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RECOVERY OF FATTY MATERIALS FROM EDIBLE OIL REFINERY EFFLUENTS

Wendelin C. Seng

Swift and Company

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RECOVERY OF FATTY MATERIALS FROM EDIBLE OIL REFINERY EFFLUENTS

By

Wendelin C. Seng

Grant 12060 DQV
Program Element 1B2037

Project Officer

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U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

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ABSTRACT

New full scale equipment and modification to the existing standard waste treatment equipment were installed at the Swift & Company modern, high-volume, edible fat and oil refining plant at Bradley, Illinois, complete with necessary controls and instrumentation to study methods for removing and upgrading the fatty materials for resale.

Concurrent with the above, an in-plant survey was conducted. The waste streams were characterized as to source, flow rate, and ether solubles, suspended solids and BOD content.

Many commercially available synthetic acrylamide polymers were laboratory tested as flocculants in combination mainly with alum for plant waste water clarification. Four were tested over several months at Bradley. All were found very effective, provided that suitable pH levels and dosage were used.

Cathodic protection devices and impressed current successfully controlled corrosion and build-up of solids on the walls of the existing Skimmer and Air Flotation Units, but statistically significant enhancement of flocculation was not shown. However, other concurrent and later work by Swift at other plants has shown impressed current is a valuable aid to waste water clarification.

Several instruments and controls were evaluated relative to the water clarification system.

Concurrently, a DeLaval PX-213 bowl opening, disc stack, centrifuge was tested to concentrate and upgrade the removed fatty materials after caustic and sulfuric acid treatment. The system was capable of handling in one shift all the material removed over 24 hours.

An overall economic evaluation indicated the 7000 pounds of oil recovered (99% ether soluble), valued at 4-1/4 to 4-5/8 cents per pound, would offset 60% of the total daily direct operating costs for the waste treatment system, including the oil reclaiming system.

This report was submitted in fulfillment of Grant No. 12060 DQV (formerly WRPD 185-01-(R-1)-68) by Swift & Company under the sponsorship of the Environmental Protection Agency. Work was completed as of December 30, 1970.

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New full scale equipment was added to existing standard waste treatment equipment at the Swift & Company Edible Oil Refinery at Bradley, Illinois. Synthetic acrylamide polymer flocculants with alum, and impressed current, were evaluated for removal of fatty materials from the plant waste water. An in-plant waste water survey was made. A DeLaval PX-213 bowl opening, disc stack centrifuge was successfully tested to concentrate the removed fatty material after caustic and sulfuric acid treatment. The 7000 pounds daily of recovered oil (98% ether soluble), worth 4-1/4 to 4-5/8 cents per pound, could offset 60% of the total waste treatment direct operating costs. ~~(Seng-Swift & Company)~~ (EPA)

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The project was originally developed by Dr. D. R. Erickson, et.al., and Mr. Earle Fritz. Mr. W. C. Seng was Project Director.

The design, construction, operation, and report preparation dealing with the Bradley facilities were performed by a team consisting of Messers. C. Berry, P. G. Bowman, P. C. Houle, J. Keigher, J. G. Killebrew, J. R. McFarland, and W. C. Seng.

Analytical work was done by Messers. R. Gregory, W. D. Pohle, and M. L. McHugh, et.al.

Mr. J. L. Shank, with able assistance from Mr. J. R. Newman, performed the laboratory screening studies and evaluations on polymers and flocculation for waste water clarification.

Mr. H. T. Anderson handled installation, evaluation, and reporting on the cathodic protection devices for waste water clarification.

Statistical analyses were performed by Messers. T. V. Kueper, H. D. Cook, and L. H. Jones.

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SECTION I

CONCLUSIONS

1. Installation of the new waste water clarification chemical treatment equipment and controls resulted in very substantially improved performance as to final effluent quality. However, because the system is undersized and because substantial periods of high plant waste loading occur, an average effluent containing 400 ppm suspended solids, ether soluble, and BOD cannot be maintained consistently even though overall average removal efficiencies of 90% were obtained. The data obtained would facilitate design of new facilities to handle such wastes and produce an effluent of any desired final composition.

2. The four commercially available synthetic acrylamide polymer flocculants used in combination with alum for waste water clarification all performed about equally well. Best results were achieved for both the Skim tank and the Air Flotation cell when the final Air Flotation pH was in the range of 3.5 to 6.0. For the Air Flotation cell, good results were obtained at all alum dosages ranging from 100 to 700 ppm, provided the pH was consistent with the 3.5 to 6.0 range. The relationships between initial and acid adjusted pH, alum dosage, final pH, and minimum turbidity of the waste water are summarized in Figure 25.

3. The In-Plant Survey showed that most of the water flow and contaminant loading come from general clean-up operations and are not correlatable with product production rates.

4. Use of cathodic protection devices and impressed current successfully controlled corrosion and build-up of scale and fat on walls of the Skimmer and Air Flotation units. However, it was not possible to demonstrate a beneficial effect on effluent clarity. However, other concurrent and later work by Swift at other plants has shown impressed current used under proper conditions is a valuable aid to waste water clarification.

5. The new equipment installed to upgrade the quality of the removed fatty materials through chemical treatment and centrifugal separation functioned very successfully. A recovered oil containing an average of 99% ether

solubles was obtained at recoveries averaging over 95%. Daily value of the 7000 pounds thus recovered at today's conservative price of 4-1/4 to 4-5/8 cents per pound is $298 to $320. This represents 60% of the total waste treatment direct operating costs.

SECTION II

RECOMMENDATIONS

The marketability and value of the recovered oil is of vital importance to offsetting the cost of the waste treatment system. A study is recommended to further explore markets, define quality requirements and value, and determine justifiable additional processing methods.

Further research is recommended on the use of impressed current-cathodic protection systems to enhance clarification of waste waters. Parallel testing procedures, however, are definitely indicated.

SECTION III

INTRODUCTION

The overall objectives of this project were to establish a flexible and complete effluent treatment facility at the Bradley, Illinois, Refinery of Swift & Company, and then to use these facilities to determine the most effective and economic methods to remove the fatty materials from the effluent and produce an effluent containing 400 ppm BOD, 400 ppm ether solubles, and 400 ppm suspended solids, or less, suitable for discharge to the Kankakee, Illinois, sewer system. It was a further principal objective of this project to upgrade the quality of the recovered fatty materials such that a more salable product could be obtained which would offset part or all of the cost of the waste treatment.

On July 10, 1968, Swift & Company accepted an EPA Research & Development Grant of $249,307 or 70% of project cost, whichever was less.

The Bradley Refinery is a modern, high-volume, edible fat and oil refinery engaged in all types of processing. Before the initiation of the Grant, it was equipped with existing standard sewage treatment facilities consisting of a large Skim Tank unit and an Air Flotation cell comparable in design to a Pacific Separator.

In the United States, there are about 250 to 300 plants processing about 18 billion pounds of edible fats and oils annually. The effluent of these plants is principally fatty material which is difficult to treat in present sewage facilities and represents an economic loss. Information developed through this Grant will aid all plants that handle any type of fatty materials.

The scope of the work included:

EQUIPMENT ADDITION AND MODIFICATION

Full scale new equipment installation and modifications were made to the existing facilities and were used to carry out the studies.

IN-PLANT SURVEY

A complete survey of the individual waste streams originating in the plant was conducted. Each stream was characterized as to flow and contaminant composition in terms of suspended solids, ether solubles, and BOD, relative to the pounds of product processed in each area.

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EVALUATION OF FLOCCULANTS

Work prior to the Grant had indicated that a number of commercially available synthetic polyacrylamides were effective materials when used in combination with coagulants such as alum for removal of waste materials from fat and oil processing. The necessary chemical tanks, metering pumps, and pH control equipment were installed as part of the new facilities. A number of synthetic polymer floccing agents were tried on a laboratory scale to determine optimum pH and dosage levels and to determine the relative performance of each. Four of these polymers were evaluated in the full scale facilities. Swift & Company is actively engaged in developing such floccing agents, and a number of Swift's products were tested.

INFLUENCE OF CATHODIC PROTECTION DEVICES

The technology of cathodic protection for corrosion control is well known, and such equipment was installed in the existing Skim Tank and Air Flotation units. However, an interesting and potentially useful side effect of cathodic protection had previously been observed at a Swift & Company packing plant. A flocculant was being tested in one of the catch-basins which was cathodically protected for corrosion purposes. It was subjectively observed that the presence of an impressed voltage increased the effectiveness of the flocculant. Therefore, devices were installed in the Skim Tank and Air Flotation units which allowed a study of the effects of various impressed voltages on the efficiency of flocculation.

PROCESS CONTROL AND INSTRUMENTATION

A number of process controls and instruments were installed to enable optimum operation and study of the system. Further, these instruments and the methods of control were evaluated. They included:

1. Flow control valves and recycle pipe lines to maintain a continuous average flow through the Waste Water Clarification System.

2. A magnetic flow meter and recorder to monitor the total flow rate through the system.

3. Automatic pH measurement and acid addition equipment to adjust the pH of the waste stream to the Skim Tank.

4. Continuous turbidity, dissolved oxygen, and temperature measurement probes, and a recorder for same, on the chemically treated waste effluent.

5. A continuous total carbon analyzer to monitor the treated effluent.

6. Necessary controls for operation of the oil recovery equipment.

OIL RECOVERY

This was one of the more important areas studied since it was here that at least a part, and possibly all, of the cost of waste treatment could be recovered.

Preliminary laboratory work had shown that the recovered waste grease skimmings could be treated with caustic to pH 10, followed by the addition of sulfuric acid to a level of pH 2.5, all at 170°F, and then the material could be separated in a centrifuge thereby recovering an oil phase containing in excess of 90% ether solubles.

Full scale equipment was installed capable of treating in a single shift all of the waste skimmings recovered in 24 hours. Basically, the equipment consisted of two 6500-gallon tanks for chemical treatment of the skimmings and a DeLaval PX-213 bowl opening centrifuge for subsequent separation.

SECTION IV

EQUIPMENT ADDITION AND MODIFICATIONS

GENERAL

The first objective of the Grant was the installation of new equipment, process controls, instruments, and modification of existing equipment. The overall process flow and descriptions of the major equipment, both new and existing, will be covered in this section.

Figure 1 is a simplified process flow diagram for both the waste water clarification and the oil recovery systems. Photographs, Figures 2 through 13, illustrate the whole system. Figure 2 is an over view of the existing Skimmer unit (left side) and the Air Flotation cell (middle). Figure 3 shows the new waste treatment building, the two agitated waste grease treatment tanks, and the storage tank for the dilute acid water phase from the DeLaval centrifuge in the oil recovery system. The building is located to the left side of Figure 2 equipment and contains essentially all the new equipment except for the large tanks shown in Figure 3, and certain other items as made clear below. All new equipment is powered through the enclosed motor control center (Figure 13) in the building.

When the word, "existing," is used it will mean that the particular item of equipment existed before the Grant.

WASTE WATER CLARIFICATION SYSTEM

Process Flow and Equipment Description

All the plant waste drains into an existing below-ground concrete sump (upper left hand corner, Figure 1) having an effective capacity of about 3 minutes at the typical plant flow rate of 280 gallons per minute. Two existing 900 gallon per minute pumps are used to move the waste flow to the existing Skim unit. A 3 inch diameter recycle line and float control valve were installed at the process sump to average the flow forward. Previously, the flow was intermittent, i.e. the pumps turned on at high level and turned off at low level. Originally, it was planned to install an automatic diaphragm air operated valve modulated by an air bubble tube sensing the level in the sump. However, it became known that the pumps could not tolerate in excess of a 45 psi back pressure without blowing out the packings. Therefore, the recycle float valve line was installed as a first step. It has enabled maintaining a continuous aver-

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age flow forward, except that an operator must adjust a downstream manual valve if the plant flow rate exceeds a rate change of ± 15%, approximately.

Before reaching the Skim tank, the waste flow (from underground header) passes through a "chemical mixing loop" (Figure 4) consisting of 3 inch diameter pipe arranged as a horizontal hairpin turn 10 feet long. The inlet (bottom) section of this mix loop is Teflon lined pipe, and the rest is type 316 stainless steel. Near the inlet end, the water phase from the DeLaval Centrifuge (oil recovery system) is recycled and injected into the first (left) tee and into the waste stream. Sulfuric acid (66° Baume) is injected into the middle tee under automatic control for adjustment of the raw waste pH.

Five feet downstream from the acid addition point, a 1 gpm sample stream is directed through a Union Carbide pH probe cell (inside the stainless sheet metal box). The pH signal inputs to a Union Carbide Model 1420 Water Monitor Instrument (Figure 5) located in the new waste treatment building. The pH signal then inputs to a Foxboro Model 62H4E Electronic Controller with a proportional band and reset which, in turn, adjusts the rate of 66° Baume sulfuric acid from a BIF Simplex Propsuperb Pump, Model 1731-22-4816, maximum capacity 54 gallons per hour (Figure 6, left center). The resultant pH is recorded on an Esterline Angus Model E1124E Multipoint Recorder.

The waste flow then proceeds around the chemical mix loop in turbulent flow and exits through a Brooks Model 7103-D15 Standard Magnetic Flow Head with Teflon lining and equipped with a continuous electrode cleaning device. The output of the magnetic flow meter is recorded on a Brooks Model 7611 Recorder with a 24 hour circular chart and totalizer. Maximum capacity is 750 gallons per minute but has been spanned for 0 to 600 gpm.

The waste flow proceeds to the Skimmer unit which has an effective length of 36-1/2 feet, a width of 10 feet, and a liquid depth of 5 feet for an overall retention of 13,700 gallons or a nominal retention time of 45.7 minutes at 300 gpm. The Skimmer is equipped with surface scraper blades to skim off the grease and deliver it via a cross conveyor to an existing steam coil heated 400 gallon tank near the effluent end (Figure 7).

No provisions are made in the Skimmer for continuous removal of settled solids. It must be cleaned out approximately once a month. Two existing Chicago pumps, operated by float

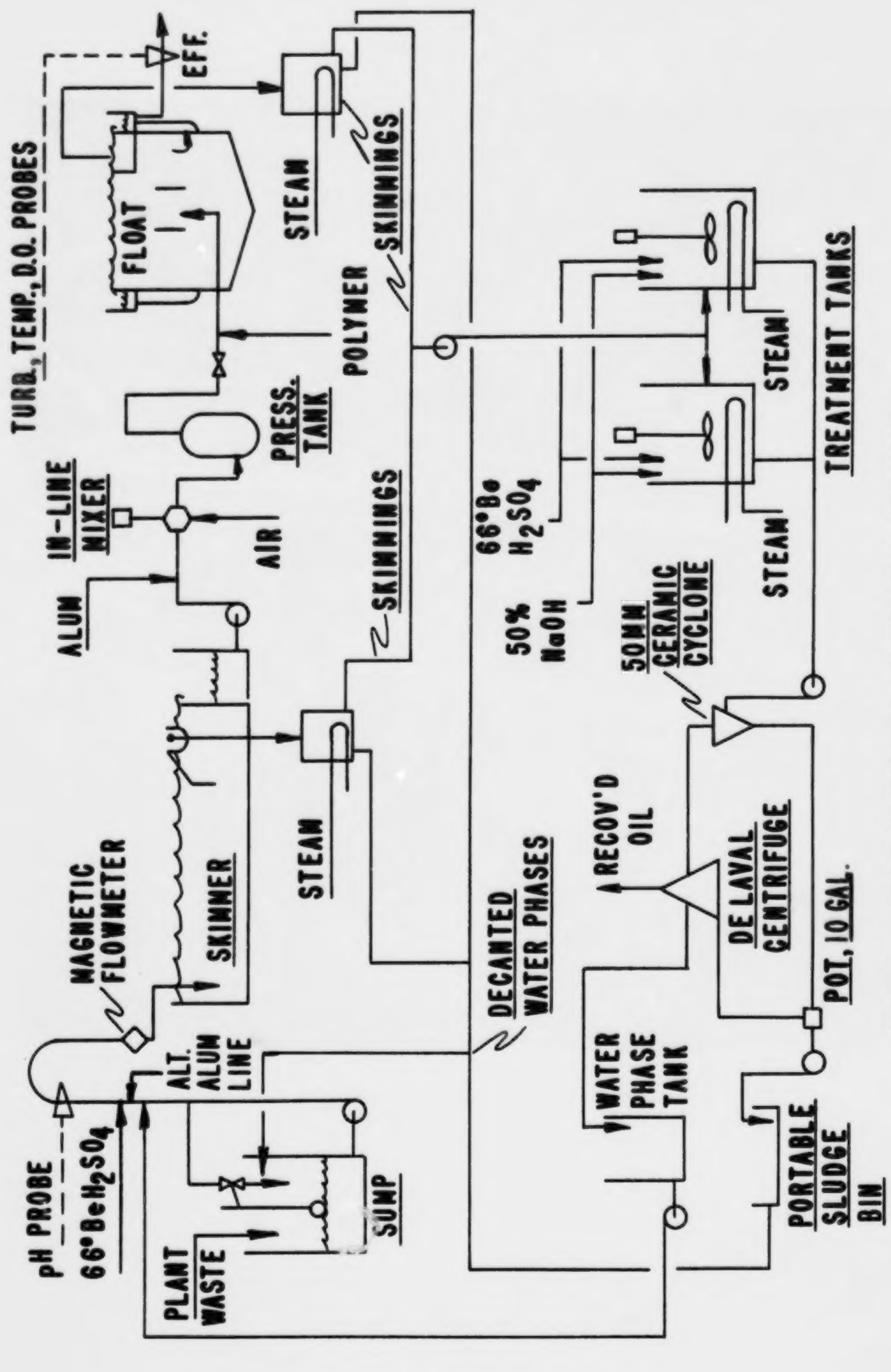
pH PROBE
66°BeH$_2$SO$_4$
PLANT WASTE
SUMP
ALT. ALUM LINE
MAGNETIC FLOWMETER
SKIMMER
STEAM
DECANTED WATER PHASES
WATER PHASE TANK
PORTABLE SLUDGE BIN
POT, 10 GAL.
DE LAVAL CENTRIFUGE
RECOV'D OIL
50MM CERAMIC CYCLONE
SKIMMINGS
ALUM
AIR
IN-LINE MIXER
PRESS. TANK
50% NaOH
66°Be H$_2$SO$_4$
STEAM
STEAM
STEAM
TREATMENT TANKS
POLYMER
SKIMMINGS
STEAM
FLOAT
TURB., TEMP., D.O. PROBES
EFF.

FIGURE 1. BRADLEY WASTE TREATMENT FLOW DIAGRAM

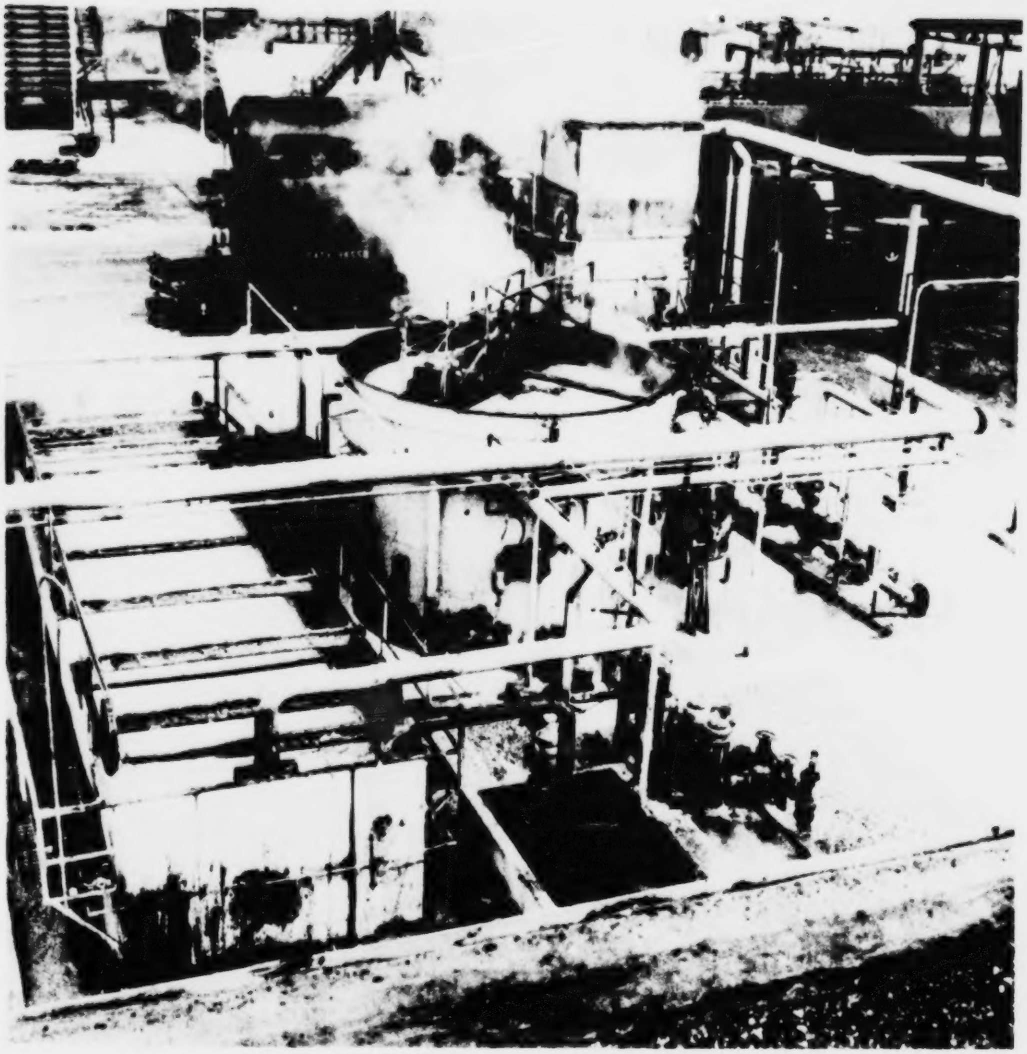

FIGURE 2: OVERALL VIEW OF WASTE WATER CLARIFICATION SYSTEM

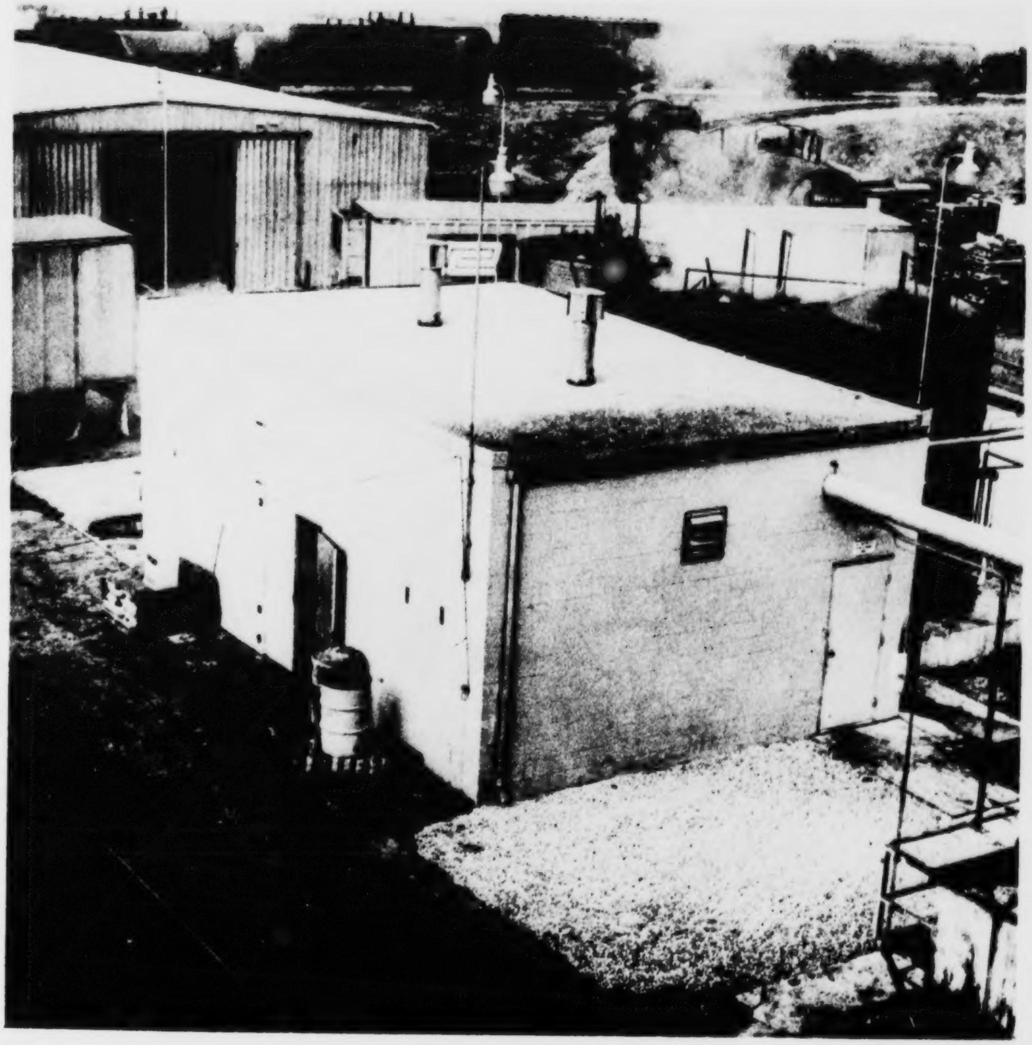

FIGURE 3: NEW WASTE TREATMENT BUILDING

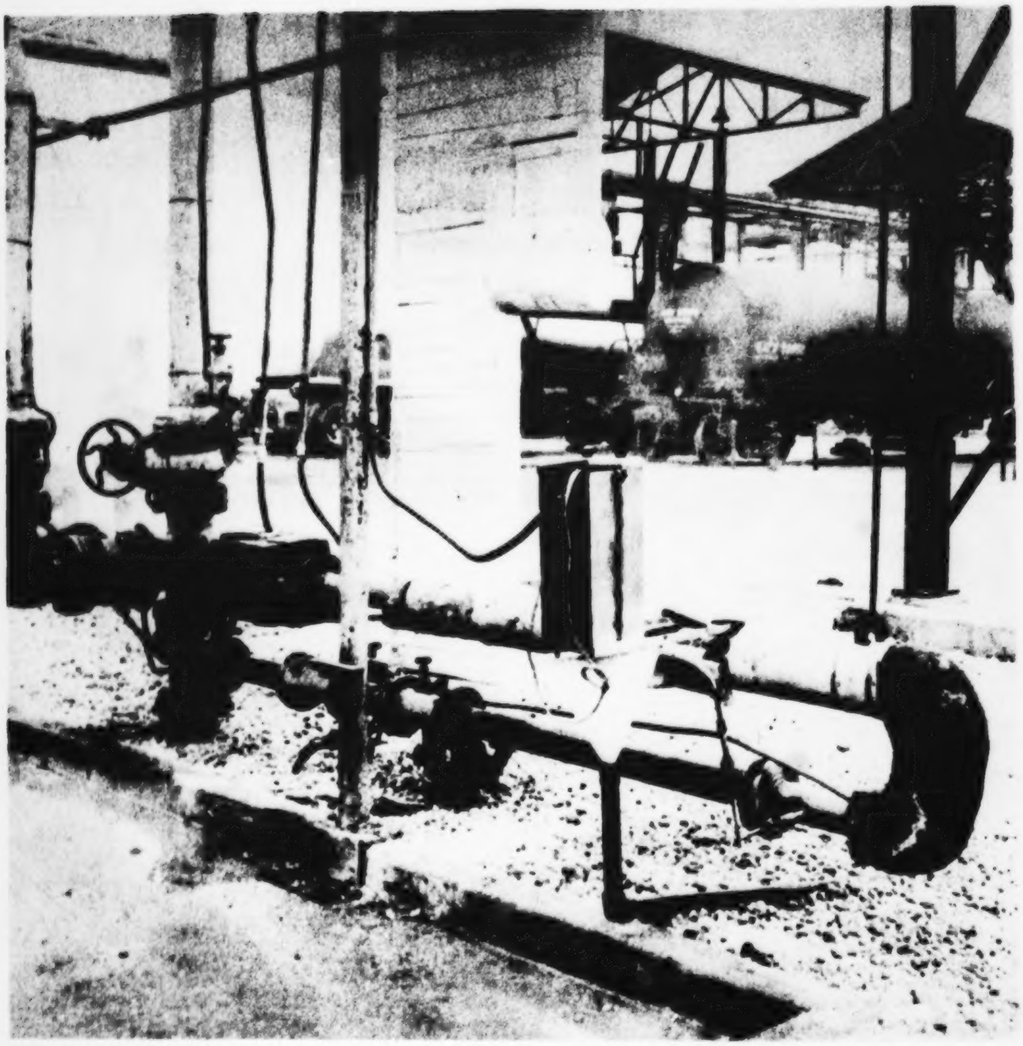

FIGURE 4: CHEMICAL MIX LOOP WITH pH PROBE CHAMBER, AND MAGNETIC FLOWMETER

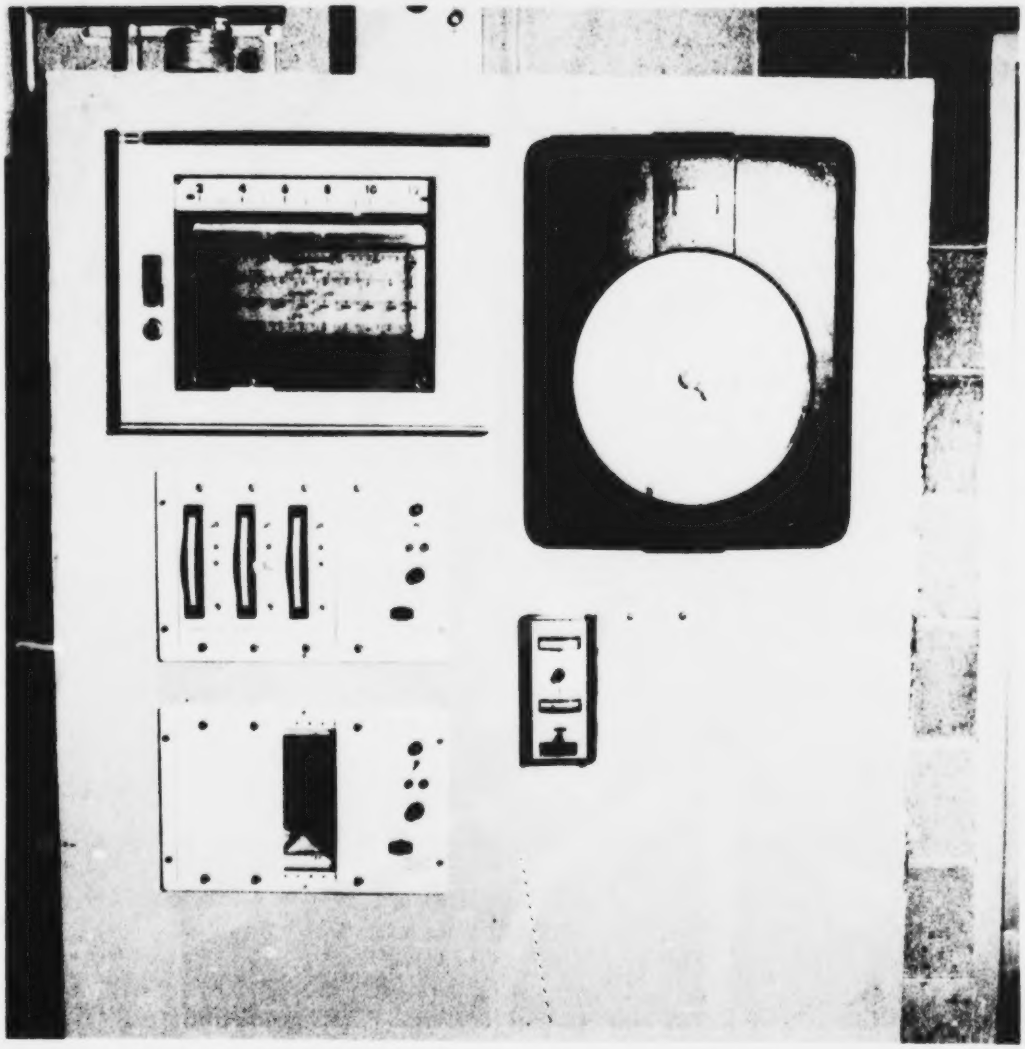

FIGURE 5: INSTRUMENT PANEL, WITH TEMPERATURE, DISSOLVED OXYGEN, TURBIDITY, AND pH INDICATORS (left middle) AND RECORDER (top left), MAGNETIC FLOWMETER RECORDER (top right), AND CONTROLLER FOR ACID PUMP (lower right)

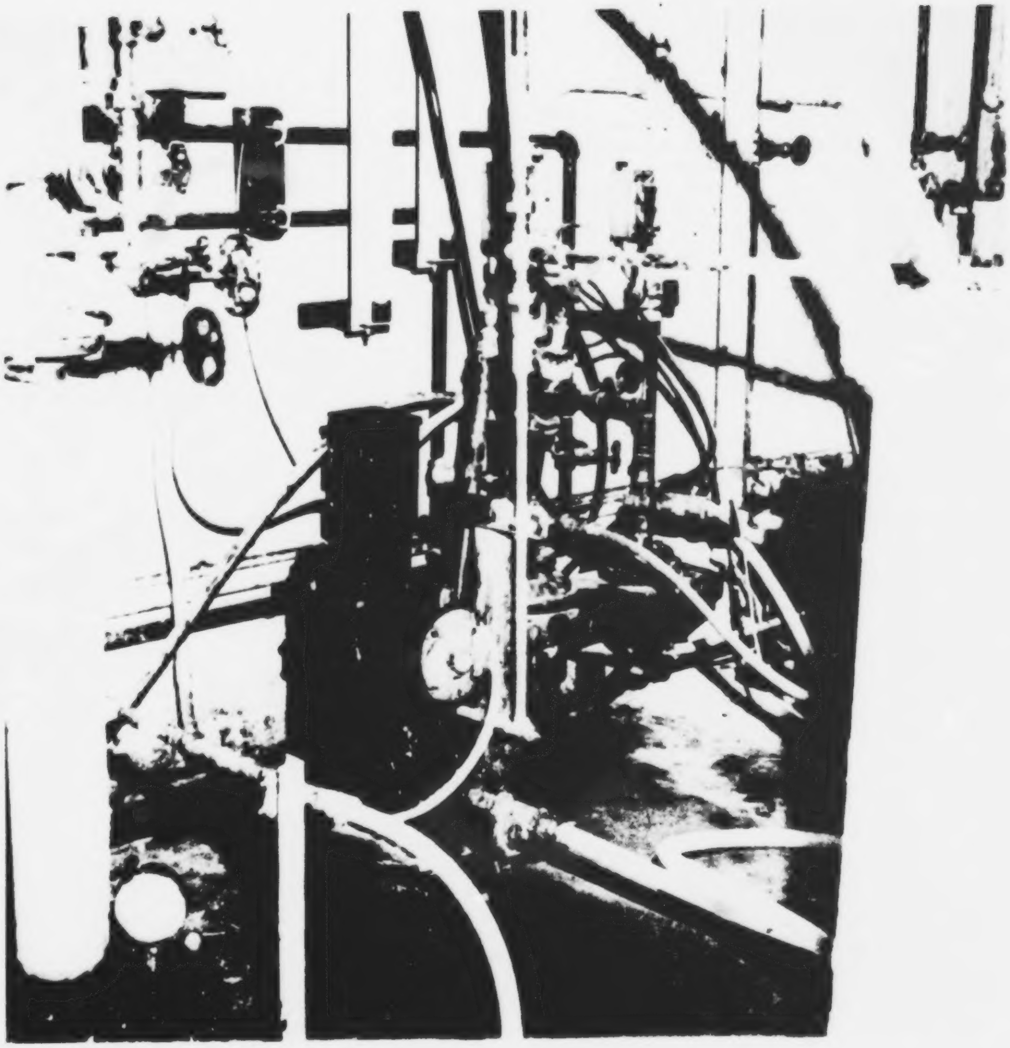

FIGURE 6: BIF AUTOMATIC ACID PUMP (left center), CANNED ACID (middle center) AND CAUSTIC (right center) TRANSFER PUMPS

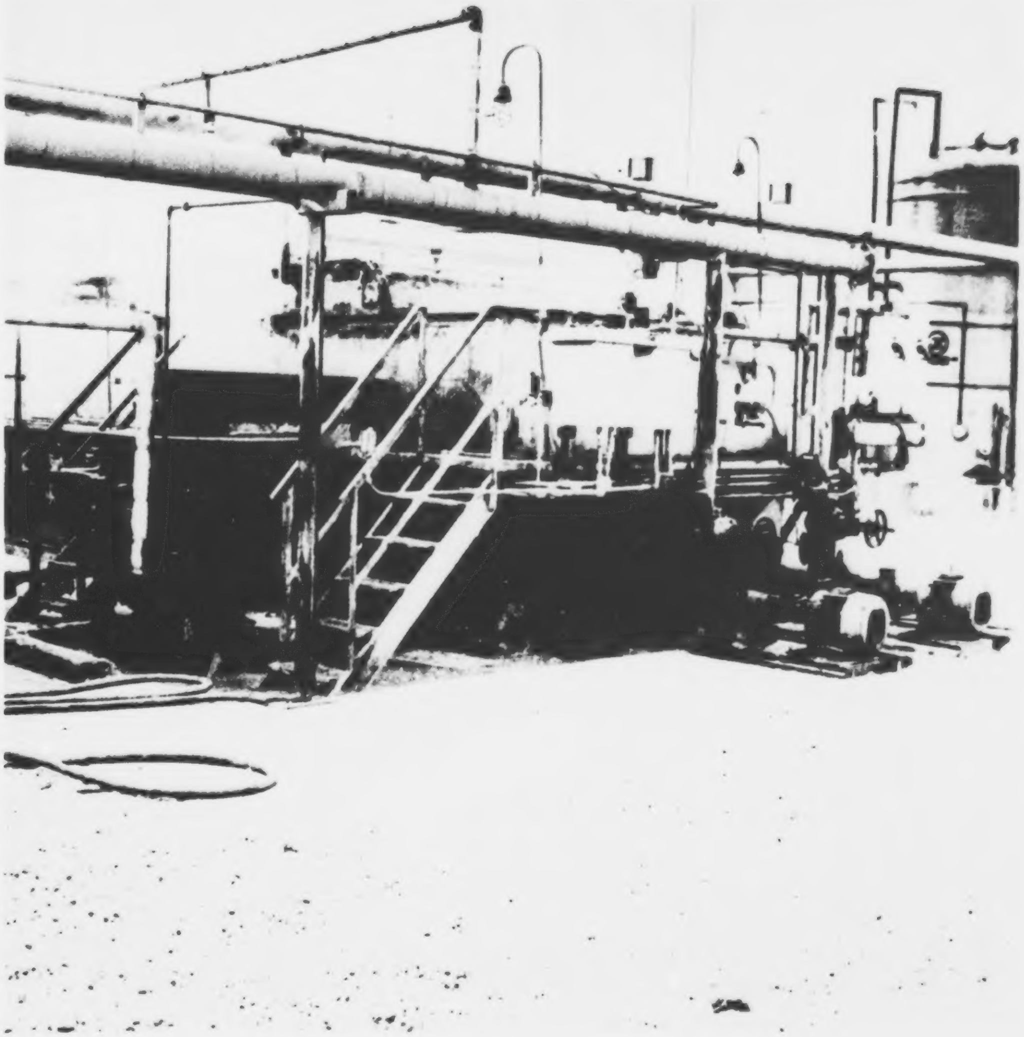

FIGURE 7: SKIMMER UNIT, EFFLUENT END, AND "SIDE TANK" FOR REMOVED GREASE SKIMMINGS (left center)

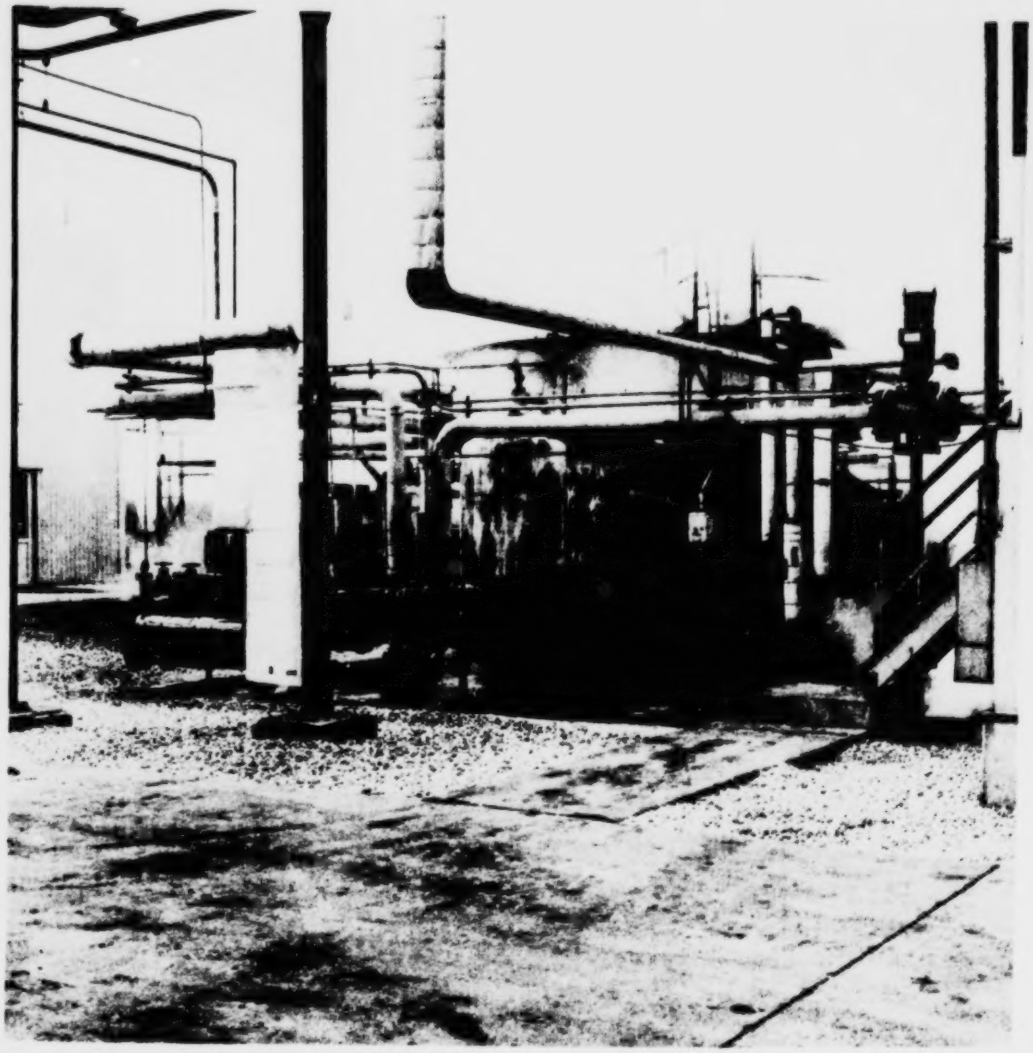

FIGURE 8: AIR FLOTATION CELL, WITH IN-LINE BLENDER (far right center) IN SUPPLY HEADER, AND PRESSURE RETENTION TANK (center)

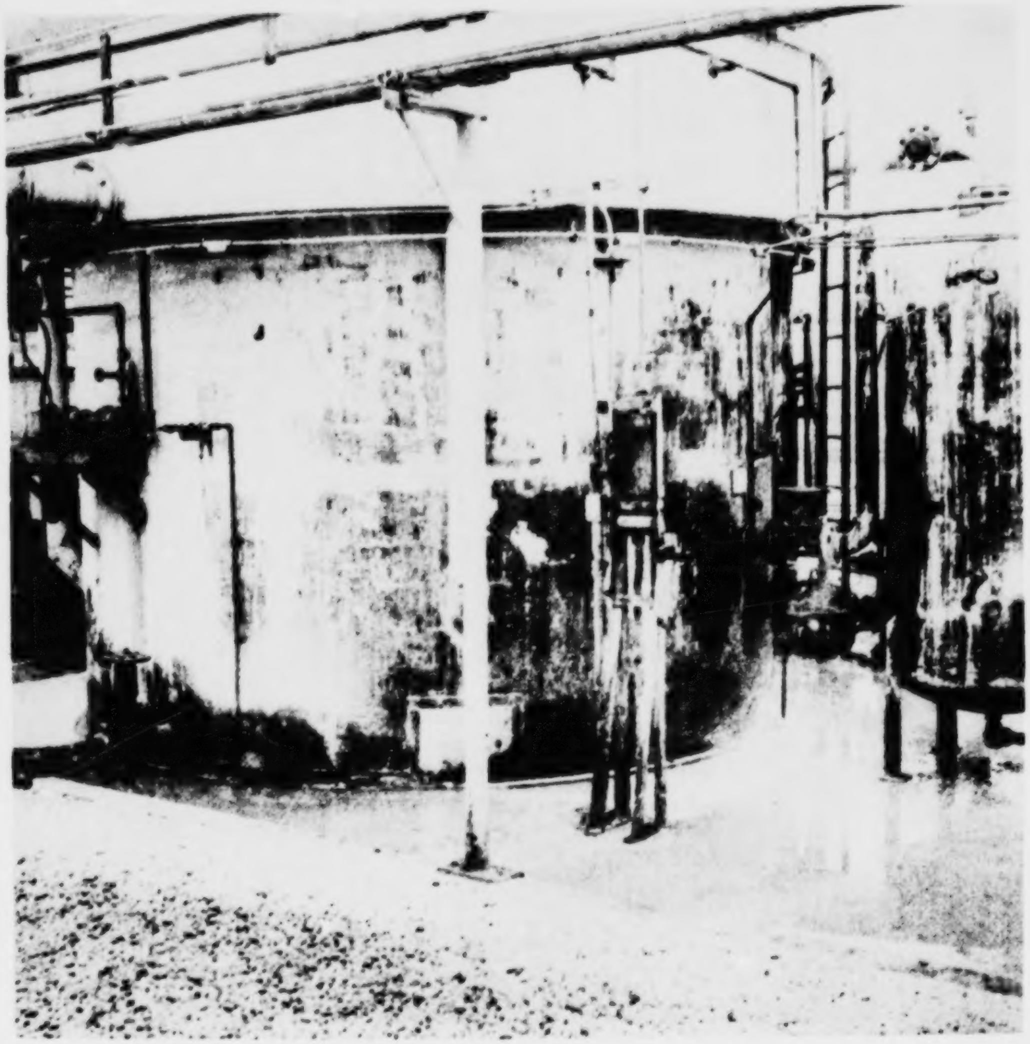

FIGURE 9: (right to left) PRESSURE TANK, MANUAL BACK PRESSURE VALVE, POLYMER ADDITION PIPE, AND AIR FLOTATION CELL. TREATED EFFLUENT SAMPLE PUMP (far left center).

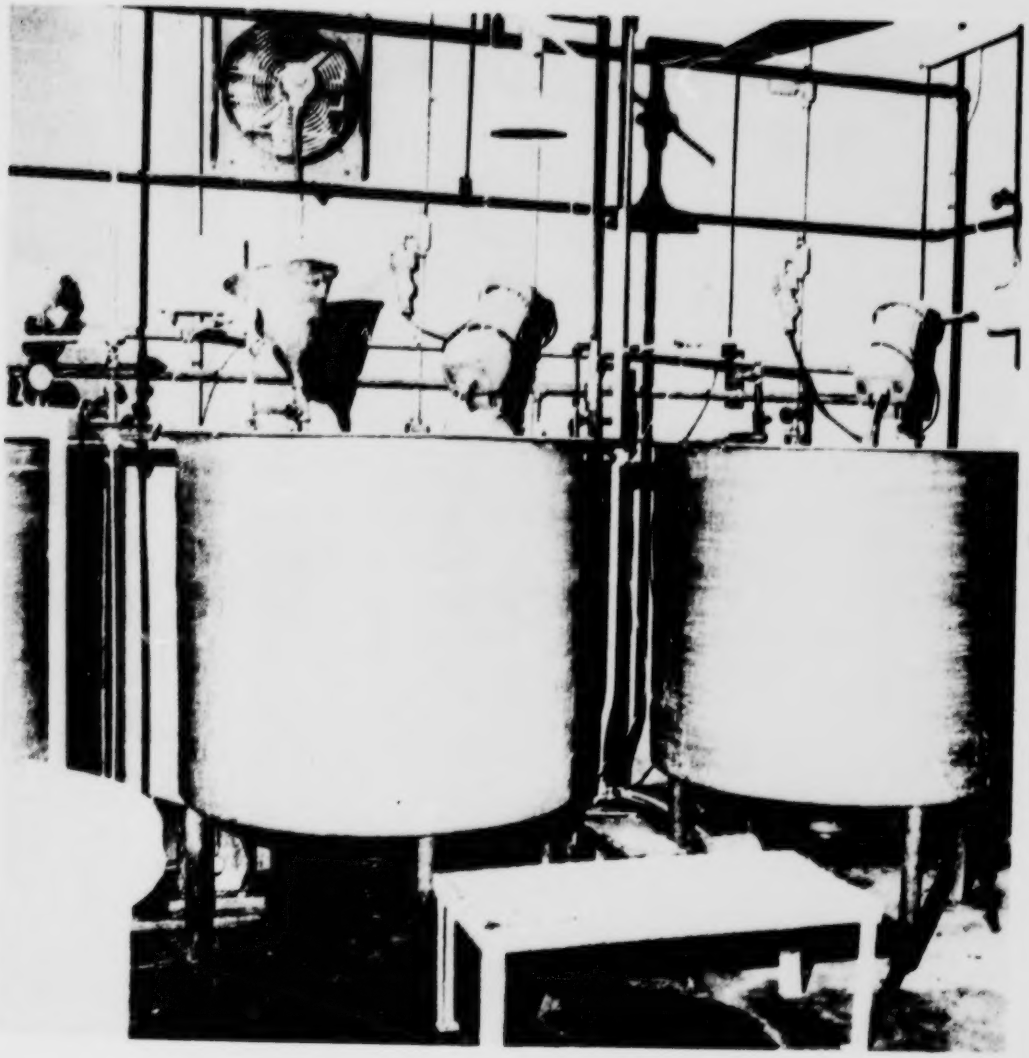

FIGURE 10: ALUM AND POLYMER SOLUTION TANKS AND METERING PUMPS

switches located in the effluent sump of the skim tank, carry the waste stream through a Mixing Equipment Company Model 4-LBC-150 Lightnin' Line Blender (Figure 8, far right center), equipped with a 1.5 HP, 230/460 volts, 60 cycle, 3 phase TE motor. Internals are of type 316 stainless steel construction. Air is injected directly into the bottom of the mixer under a pressure of 30 to 45 psi at a rate equivalent to at least 4% by volume of the water processed.

The waste stream proceeds through an existing pressure tank, a manual valve, and then into the flotation cell (Figure 9). A pressure of at least 30 pounds and preferably 40 pounds is maintained in the pressure tank.

A 20% alum solution is injected 20 feet upstream from the in-line mixer. Similarly, a polymer at 0.2% solution is injected just downstream of the manual valve after the pressure tank (Figure 9). Two 300 gallon solution tanks for polymer and one 300 gallon solution tank for alum, with one positive displacement metering pump for alum and one for polymer are located in the new waste treatment building, (Figure 10). All tanks are identical, of Atlac 382 Polyester Fiberglass reinforced construction, and were obtained from the Resin-Fab Corporation. The two metering pumps are Milton Roy Model MR1-48-142R Milroyal Simplex, Teflon packing, self-lubricating, polar crank design controlled volume pumps, with double ball checks, column valve liquid end, carpenter 20 construction, and 1/2 HP TE motors. The stroke length is manually adjustable from 0 to 100% capacity while the pump is operating. Maximum capacity is 88 gph, each.

The existing Air Flotation cell is not a commercially designed unit, but was built in general conformance to a Pacific Separator. It is 13 feet 6 inches in diameter, by 10 foot high liquid height, with a nominal volume of 11,000 gallons. It has a shallow (18 inch) bottom cone and center drain outlet, equipped with a variable speed surface skimming sweep-arm and bottom scraper, both driven with the same drive. Nominal retention time is 36 minutes at 300 gallons per minute. Skimmings are removed via a 3 feet long radial trough at one point in the circumference and are discharged by gravity into an existing 850 gallon steam coil heated steel tank. The clarified effluent discharges by gravity into an underground sump (Figure 2, lower right) from where it is normally pumped to the 200 foot by 300 foot lagoon on the premises. Effluent from the lagoon goes to the Kankakee Municipal Waste Treatment Plant. However, the Air Flotation effluent can be by-passed directly to a sewer line going to the Municipal Treatment System.

A Worthington Model 3/8 CNG-4 centrifugal pump, Worthite construction, is located directly under the effluent header from the air flotation cell (Figure 9) and pumps a sample stream to the Union Carbide dissolved oxygen and turbidity probe assemblies inside the waste treatment building. The temperature probe is located in the air flotation cell effluent at the point of exit from the cell. Turbidity, temperature, and dissolved oxygen readings are indicated on the Union Carbide Model 1420 Water Monitor instruments (Figure 5) and are recorded on the above mentioned Esterline Angus recorder.

Evaluation of Controls and Instruments in the Waste Water Clarification System

General:

Reference should be made to the above portion of Section IV and to Figure 1 for details on the specifications of the controls and instrumentation and their location in the process.

Process Sump Recirculation Line and Float Valve:

The function of this valve is to provide a continuous average flow from the process sump to the Skimmer unit. Originally, it was intended that an automatic diaphragm operated valve modulated by an air bubble tube level sensing device in the process sump itself would be used to obtain an average flow forward, instead of the original on-off pump forward situation. However, it became known that the two 900 gpm capacity process sump pumps could not tolerate a back pressure in excess of 45 psi without blowing out the pump packings. Therefore, a recycle line and butterfly valve arrangement was installed as a first step. This arrangement has enabled a continuous flow forward into the waste treatment system most of the time and could handle fluctuations in the waste flow of ± 15% from a given setting. However, if this range is exceeded, then an operator must adjust the downstream manual back pressure valve to accommodate the different flow rate. For this reason, it would be desirable to install an automatic flow control valve, modulated by the level in the waste sump, in addition to the butterfly recycle valve. Such an automated valve would be important to eliminate the operator attention required and to prevent overflowing of the sump or, on the other hand, pumping it dry. The recycle line, however, has prevented a buildup and hardening of grease on the surface of the water in the sump and would continue to avoid excessive back pressure on the two transfer pump packings.

Air Flotation Unit Recycle Line:

In order to maintain a continuous flow to the air flotation cell, a recycle line was installed to take water from the air flotation cell effluent sump and pump it back to the inlet of the Skimmer. The recycle pump is operated on and off, automatically, by means of a float switch located in the effluent sump of the Skim tank. Most of the time this recycle line is not needed since the process sump recycle line is operative and maintains a continuous flow forward through the system.

Magnetic Flow Meter on Raw Waste Stream:

The Brooks magnetic flow meter in combination with the Brooks (Bailey) flow recorder does an excellent and reliable job of measuring the raw waste flow through the system. The recorder is equipped with a 24-hour chart and with a totaling function, thereby providing a very accurate record of instantaneous and total flow through the system. The magnetic flow meter is Teflon lined and is equipped with a self cleaning probe. The lining has remained in excellent condition after several months of use and has required no maintenance. Actually, the flow through the magnetic flow meter not only includes the raw waste, but also includes the small flow of concentrated sulfuric acid used for pH adjustment and the dilute acid water being recycled from the oil recovery DeLaval Centrifuge system. These flows are so low as to be insignificant compared to the raw waste flow.

Raw Waste pH Control:

The pH control system has succeeded in eliminating the extremes of pH, that is above 10 and below 4 in the Skimmer effluent. This degree of control has very substantially improved the typical efficiency of the system. However, closer control would be desirable. To achieve this, however, would necessitate the addition of at least a 3 to 5 minute surge tank in the raw waste line, equipped with a mixer into which acid would be added.

The raw waste was found to be essentially unbuffered. A typical situation is that the raw waste pH is between 9 and 10. This requires that the acid be added at approximately 10% of the maximum BIF pump capacity of 54 gallons per hour, or 5 gallons per hour. If one is attempting to control the pH at 7, then a shift of only 0.05 gpm, or less than 0.1% of the pump output, causes the pH to vary ± 3 pH.

Originally, the Foxboro control instrument was equipped with a proportional band of 5 to 300% and the pH probe was located inside the waste treatment building 100 feet away. This resulted in a lag time of 30 seconds. Subsequently, the pH probe was relocated to a point about 5 feet downstream from the point of acid addition and the proportional band was converted to the 15 to 1000% range. The relocation of the probe reduced the lag time to about 5 seconds. This, in combination with the use of proportional band setting of 700%, substantially reduced cycling and hunting of the pH control system.

Originally, the approximately 100 feet of pipe carrying the concentrated acid from the BIF pump in the waste treatment building to the chemical mix loop was 1/4 inch black iron. However, it was rapidly found that sludge existing in the concentrated acid would plug this 1/4 inch pipe readily. This pipe was then replaced with 3/4 inch stainless steel which has functioned quite well since.

The chemical mix loop is type 316 stainless steel and, originally, the last few feet of the 66° Be acid delivery pipe entering this mixed loop was also of type 316 stainless steel. However, after about one month's operation, the acid line at the point of entry into the 3 inch diameter chemical mix loop corroded and began leaking badly at the threaded joints. So, 7 feet of the stainless steel mix loop inlet section were replaced with flanged Teflon lined pipe and tees where the 66° Baume sulfuric acid, the diluted acid water from the DeLaval Centrifuge, and the alternate alum solution lines enter the mix loop. Also the 9 foot vertical section of the pipe carrying the 66° Baume acid to the mix loop was replaced with 1 inch Teflon lined pipe. A 4 foot U-trap section was included to prevent the lighter water rising through the heavy acid. These changes have been very effective in correcting the corrosion that occurred.

However, three weeks later the Teflon lining was found to have bulged out from the pipe wall for the first 1 foot length of and over about a 30° arc of the 3 inch diameter run of the tee where the concentrated acid entered. Also, thin shavings of the Teflon were peeled up in the direction of flow in this tee and, to some extent, in the upstream tee. All other sections of the Teflon pipe were in good condition. The magnetic flow meter, which is also Teflon lined, was inspected and found to be in perfect condition. An inspection was made of the faulty tee by the manufacturer, and the conclusion was reached that the failure was due to pinhole penetration of the acid to the wall of the pipe. The tee was shortly thereafter replaced and has operated for several months without difficulty.

Air and Alum Addition to Air Flotation Cell Supply System:

Originally, both air and alum solutions were added to the suction side of the transfer pumps taking flow from the Skimmer to the Air Flotation cell. This resulted in excessive cavitation, corrosion, and erosion of these pumps, and also much of the time resulted in air binding of the pumps. Under the Grant, a Mixing Equipment Company Lightnin in-line mixer was installed in the supply pipe to the Air Flotation cell. Air, under pressure, is added directly to this in-line mixer. Alum solution is added to the pipe line about 20 feet upstream from the in-line mixer. The arrangement has functioned perfectly since its installation and it is felt that it has dramatically improved the overall performance of the system.

Turbidity Probe in Air Flotation Unit Effluent:

This device was found to be unsatisfactory primarily because the two halves of the prism came unglued on three occasions. When the unit was operative, it did measure turbidity and tracked the process quite well. It was also found that the turbidity device required cleaning about once an hour to maintain a reasonably accurate measurement.

Dissolved Oxygen Probe in Air Flotation Unit Effluent:

The dissolved oxygen probe functioned quite well except that it required cleaning once an hour to obtain reasonably accurate readings. Use of this device during the test period demonstrated that the dissolved oxygen content of the plant effluent was essentially always at saturation. In future installations it is not recommended that a dissolved oxygen device be incorporated since it does not really provide useful information that would enhance the efficiency and control of the system.

Temperature Probe in Air Flotation Unit Effluent:

This probe has operated 100% reliably.

Total Carbon Analyzer on Air Flotation Unit Effluent:

The Union Carbide Model 1212 automatic total carbon analyzer was investigated heavily over a long period of time. However, it was found unacceptable and inadequate for the purpose intended for the following reasons:

1. Stable calibration of the device on standard solutions could not be achieved for more than a few hours at a time.

2. The unit is equipped with a multiple disc filter on the input sample stream. Clearances between discs range from 0.0035 to 0.0062 inches. All particles in the sample to be tested must pass through this filter. Unfortunately, much of the contaminant grease is larger than this in size and tends to plug the filter device quite rapidly in spite of automatic use of hot water for back flushing. The effect is to prevent continuous use of the device with accurate results for more than an hour or two.

3. After the sample passes through the filter, it must pass through the sample valve measuring block assembly prior to being injected into the reaction chamber. This sample valve block has a drilled hole of 1/16 inch diameter and is about 1 inch long. The sample orifice channel becomes coated and partially plugged after operation for only a few minutes. As a result, the accuracy of the device is badly affected.

For the above reasons, it was concluded that although a total carbon analyzer will accurately measure the total carbon content of a sample once it enters the reaction chamber, this unit is not practical as a continuous monitoring device. Furthermore, considering the cost, a turbidity device is considered a more practical type of instrument considering the degree of accuracy and the level of contaminants to be expected in an effluent from an oil refinery. If one was interested in monitoring BOD in the 10 ppm range, then a total carbon analyzer, no doubt, would have much greater utility.

OIL RECOVERY SYSTEM

Process Flow and Equipment Description

The bottom half of the simplified process flow diagram (Figure 1) illustrates the oil recovery system. Skimmings from the Skimmer and Air Flotation units are heated and held in the two "side tanks" as long as possible, and are then dewatered. Since these tanks are not agitated, the skimmings tend to separate into a water and oil phase, and the water phase is drained back into the process sump. The dewatered skimmings are moved with an existing positive displacement Viking pump to either one of the two large agitated plastic treatment tanks (Figure 11). Each one of these 10 foot diameter by 11 foot 9 inch high tanks, having a capacity of 6,500 gallons, can normally accept 24 hours collection of waste grease. While one is being used to collect the grease, the contents of the other are chemically treated and centrifuged.

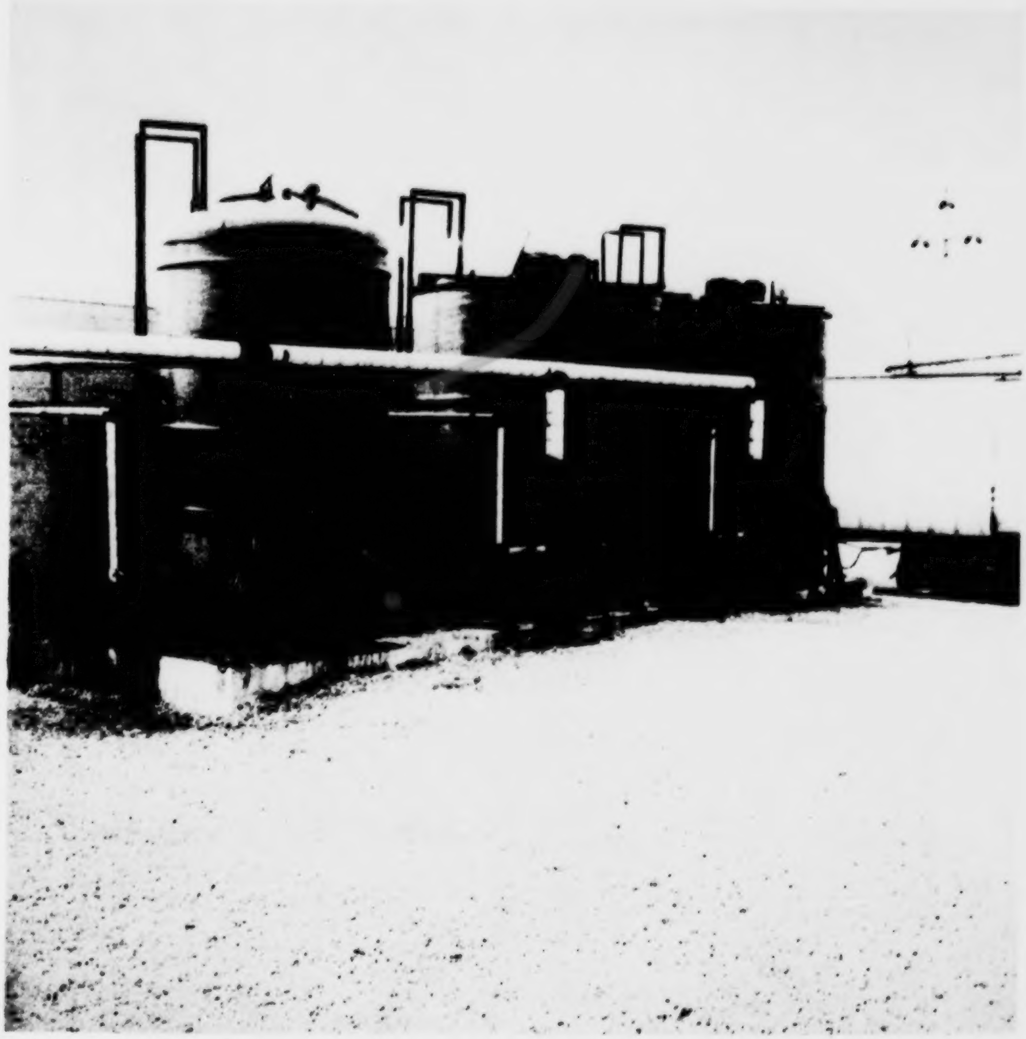

FIGURE 11: STORAGE TANK (left) FOR DELAVAL CENTRIFUGE WATER PHASE, AND TWO GREASE SKIMMINGS TREATMENT TANKS (right)

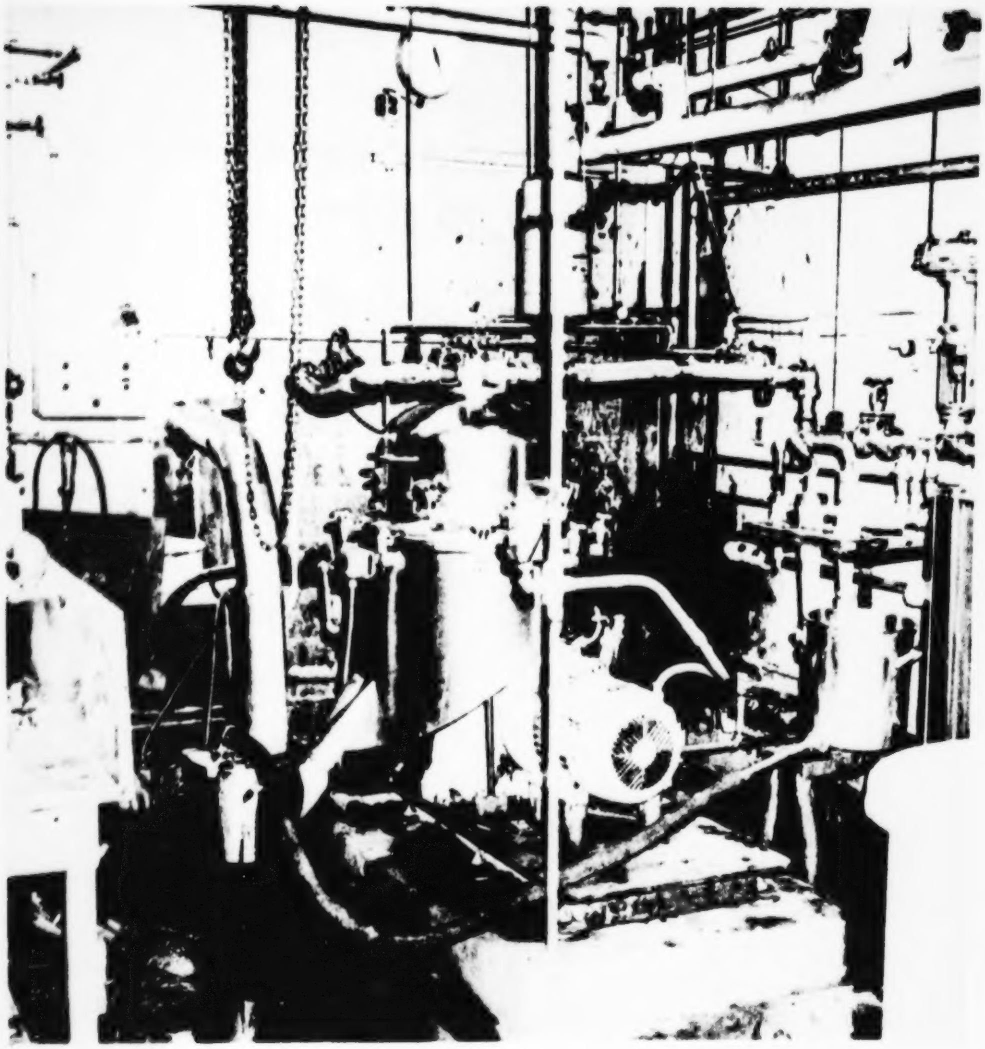

FIGURE 12: DORR-OLIVER P-50 CERAMIC CYCLONE (right center) AND DELAVAL PX-213 CENTRIFUGE

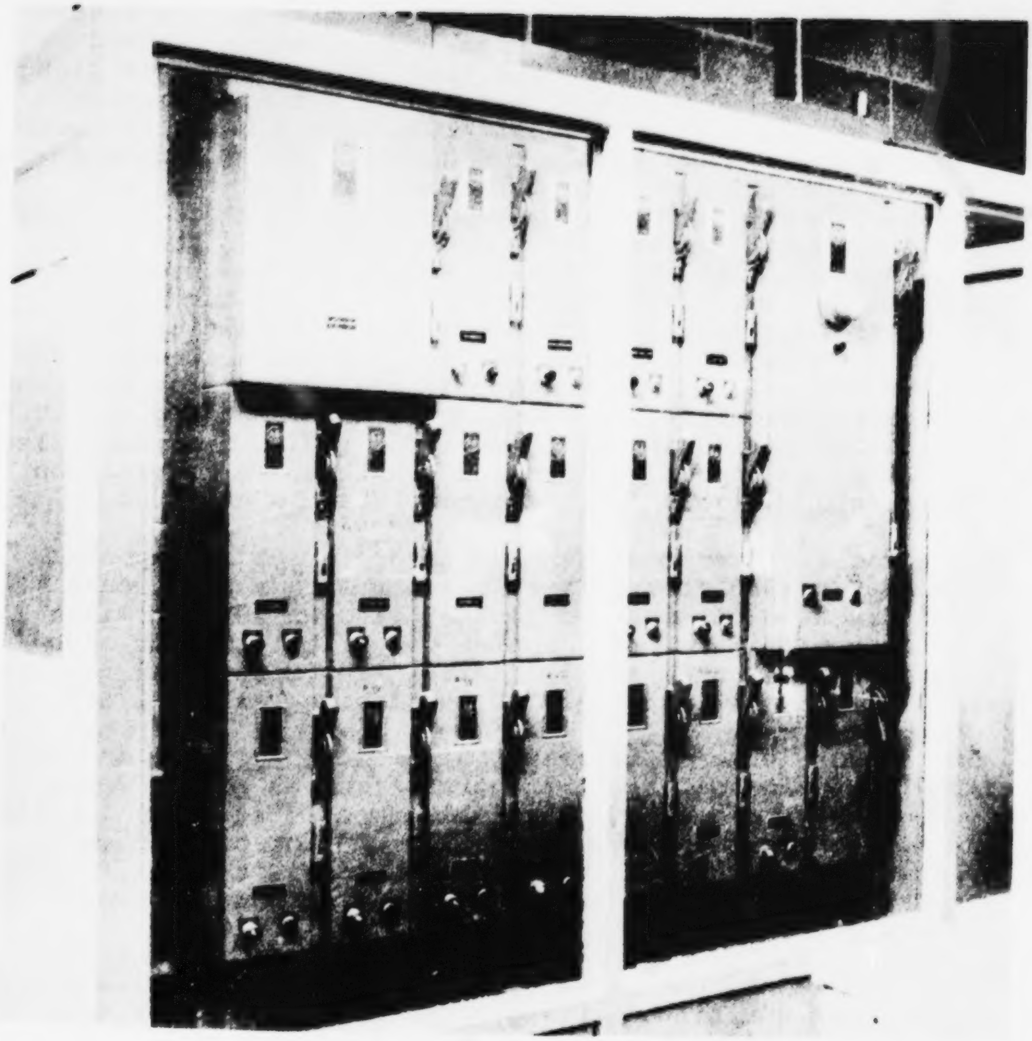

FIGURE 13: ENCLOSED MOTOR CONTROL CENTER

The two treatment tanks are constructed of fiberglass reinforced Atlac 382 polyester resin, with a 20 square foot, 2 inch diameter, double-hairpin steam coil, by the Justin Manufacturing Company. The steam coils can be removed readily from the bottom of the tank through a single flanged opening. Each tank is equipped with a Mixing Equipment Company Lightnin' Mixer, Model 72Q5, with a 5 HP TEFC motor, 120 inch shaft, dual axial flow turbines of 33 inches in diameter operating at 84 rpm, wetted parts of type 316 stainless steel. The bottom impeller is located 26 inches from the bottom, and 6 inches above the top of the double hairpin steam coil which passes radially across the center line of the tank. The steam coils are rated for 125 psi. Sarco 1/2 inch pressure and temperature regulating steam valves with filled bulb temperature sensing elements are used to control the temperature of the contents of the tank. As a backup temperature control to avoid exceeding the 200°F temperature limitation of the plastic tanks, a Sarco filled bulb actuated on-off micro switch control, in combination with a solonoid valve in the steam line, is utilized.

Sizing of the treatment tank agitators was based upon a viscosity of 850 centipoises for untreated waste grease which had an excessive oil content of over 50%. A mixing time of approximately 15 minutes was stipulated for each chemical (30 minutes total). After treatment, at 2.5 pH, the viscosity is less than 100 centipoise, all at 170°F.

When a tank is to be treated, 50% sodium hydroxide and 66° Baume sulfuric acid are transported from 55 gallon drums by means of Crane canned chemical pumps, (Figure 6) located inside the treatment building. The one for caustic is a Dynapump Model 882-E. The pump for acid is a Model SF-3/4-3/4-CI/CA20. Further details of the treatment procedure will be covered in Section VIII.

After treatment, the waste grease is transported with a Worthington Centrifugal Pump, Model 1CNG-32, with a 5 HP TEFC motor, 3600 RPM, 4 inch diameter open impeller, and Durametallic type CRO double mechanical seals, through a 50 millimeter Dorr-Oliver P-50 ceramic cyclone, and then to a DeLaval Model PX-213 bowl opening, disk stack type centrifuge, equipped with automatic cycle controls, feed valves, and all necessary accessories (Figure 12). The purpose of the ceramic cyclone is to remove as much of the sand and grit as possible from the feed to the centrifuge. The sludge underflow from the centrifuge and the underflow grit stream from the ceramic cyclone are pumped by means of a small Worthington centrifugal pump into a truck-portable scavenger bin located outside the building. The sludge pump is a Worthington 3/4 CNG-42, all Worthite fitted, plain packing, acid resistant, 3-7/8 inch impeller, with 1/2 HP TEFC motor, 1750 RPM. The portable sludge bin is 15 feet 10 inches long by 7 feet 2 inches wide by 42 inches overall height. However, the bin is equipped with a lid which is at the 30 inch level, giving an actual capacity of 2,100 gallons. The bin belongs to the Kankakee Disposal Company. The sludge is hauled away and emptied for $150 a load.

The water phase from the DeLaval Centrifuge is pumped by the pressure developed by the centrifuge to a 4,700 gallon plastic tank outside the treatment building (Figure 11). This tank was also made by Justin and is of exactly the same fiberglass and resin construction as the 2 treatment tanks, except that it has a domed top and is 8 feet in diameter with a 12 foot 6 inch straight side. Further, it has no agitator and is equipped with a direct steam injection sparge header instead of steam coils. Steam temperature and pressure controls are identical to those on the treatment tanks. Actually, steam heating is required only in the wintertime to prevent freezing. DeLaval acid water from this tank is recycled back to the chemical mix loop of the water clarification system using a Worthington Centrifugal Pump, Model 1CNG-64, all Worthite fitted with a 3600 RPM, 5 HP TEFC motor, double mechanical seals, and 6-3/8 inch diameter open impeller. The flow rate is adjusted manually to suit conditions and to spread the flow over 24 hours operation.

The clarified recovered oil from the DeLaval Centrifuge is pumped with a Model 1CNG-64 Worthington Centrifugal Pump, all Worthite fitted, with a 5 HP TEFC motor, 3600 RPM, 5-7/8 inch diameter open impeller, and double mechanical seals, to an existing storage tank in the outdoor plant tank farm for storage.

Concerning the steam coils and the two plastic treatment tanks, several weeks after operations began it became apparent that a heavy buildup of cake would form on these coils requiring maintenance and cleaning every few days to maintain heating capacity. Therefore, to enable direct steam injection, fifteen 3/16 inch diameter holes were drilled on each side of one coil section in each tank on the horizontal plain located 2 inches apart directly under the lower agitator impeller. This change for direct steam injection has been quite successful. Future units should have a direct steam sparge header, instead of coils.

SECTION V

IN-PLANT SURVEY

The sources of waste water from the Bradley Refinery can be conveniently divided into two parts: Plant Interior and Plant Exterior. Figure 14 is a schematic diagram of the major sewer lines and their origins. It can be seen that the outdoor tank farm area and tank car washing area empty into a common diverter prior to entering the hot well. All the major sewer lines from the interior of the plant enter the hot well through a common line.

A description of the flows and constituents of the two main areas and their measureable subdivisions follow. Average data are also shown in Figure 14.

PLANT INTERIOR

Plant Water Intake

The entire plant uses water at the average rate of 3800 cu ft/hr or 475 gpm. This figure includes sanitary wastes and other water that is directed to separate sanitary sewers. Figure 15 illustrates the plant water intake for a typical 24 hour period and the amounts of water used for boiler make up. The condensate from this goes to the industrial sewers directly, or after it has been used for clean up. The average flow is 900 cu ft/hr or 110 gpm.

Caustic Refining

Oil from storage tanks is treated with caustic and centrifuged to remove gums and soap-stock. These "foots" are pumped to the outdoor tank farm for sale. The oil is then washed and centrifuged and this wash water constitutes a continuous source of process waste water (Stream E, Figure 14). Typical compositions of this wash water are illustrated in Table 1. The average flow from this process is 10 gpm. Additional such tests yielded similar results.

TABLE 1

CAUSTIC REFINING WASH WATER COMPOSITION IN PPM

	ETHER SOLUBLES	BOD	COD	SUSPENDED SOLIDS
Average	1800	1240	5000	688
Minimum	874	400	3880	129
Maximum	2936	2500	7400	1470

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AVERAGE FLOW & PPM COMPOSITION

STREAM	GPM[a)]	ES	BOD	COD	SS
A	3	555	440	940	408
B	100	3300			
C	15	300	400	1000	180
D	0.23	6000			
E	10	1800	1240	5000	688
F	47	580			
G	120	6800			
H	305	4150	3670		3630

a) Flow rates are also shown on schematic diagram below.

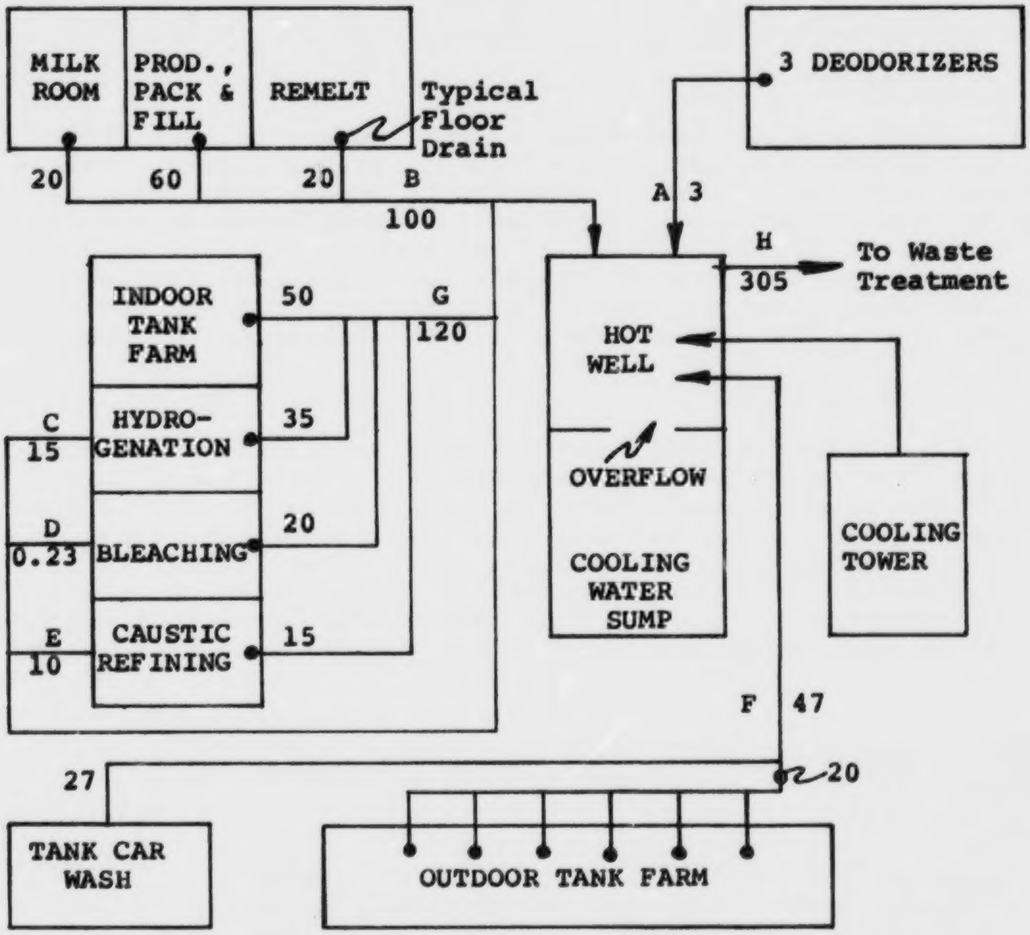

MILK ROOM
PROD., PACK & FILL
REMELT
Typical Floor Drain
20
60
20
B
100
3 DEODORIZERS
A
3
H
305
To Waste Treatment
INDOOR TANK FARM
50
G
120
HOT WELL
C
15
HYDRO-GENATION
35
D
0.23
BLEACHING
20
OVERFLOW
COOLING WATER SUMP
COOLING TOWER
E
10
CAUSTIC REFINING
15
F
47
27
20
TANK CAR WASH
OUTDOOR TANK FARM

FIGURE 14: SCHEMATIC DIAGRAM OF MAIN PROCESS SEWERS AND WATER SOURCES LEADING TO HOT WELL

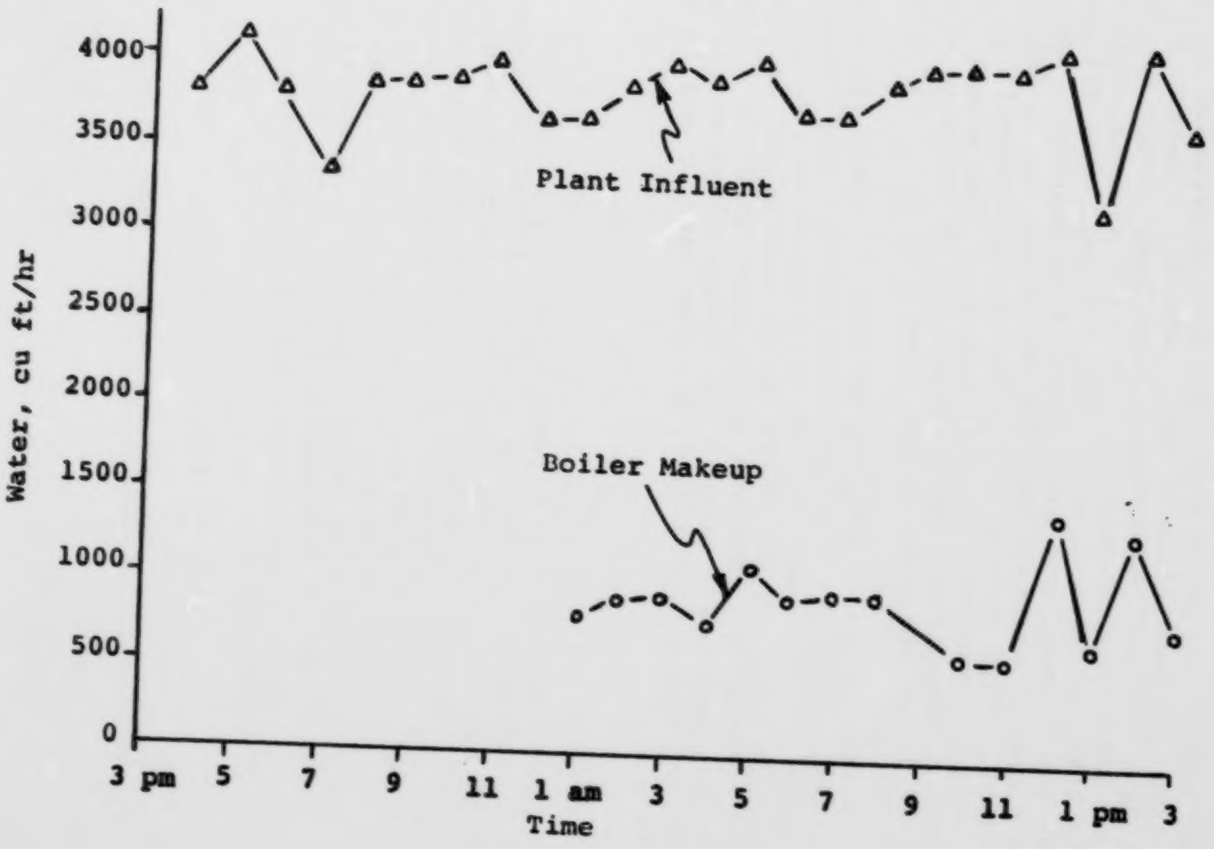


FIGURE 15: BRADLEY PLANT WATER USAGE BY METER READINGS

Bleaching

After the caustic refining step, the oil is bleached using precoat type pressure filters, and clays and asbestos for filter aids. The main contaminant that reaches the process sewer from this step (Stream D, Figure 14) are the caustic solutions that are used to clean the filters. The filters are first dry cleaned and then immersed in caustic. Whenever the cleaning solution becomes too dirty, it is dumped to the sewer. This dumping may occur daily or weekly depending on the efficiency of dry cleaning. The amount is 10 gallons of 50% caustic in 1000 gallons of cleaning water per batch. Ether solubles varied from 2000 to 10,000 ppm.

During cleaning relatively small amounts of spent filter aids are dropped on the floor and are subsequently flushed to the sewer during clean up. This is one source of suspended solids found in the waste water. Additional suspended solids find their way into the waste water when the filter aid storage areas are cleaned. The common plant practice has been to flush filter aids from burst bags or spills down the sewer.

Hydrogenation

When required, oils can be hydrogenated to provide the desired consistency for various blends. Nickel catalyst and hydrogen produced at the plant are used to produce oils with varying degrees of saturation. The main contaminants that reach the sewer from this area are very small amounts of nickel and cleaning waters. This flow (Stream C, Figure 14) is transported by a stream lift which causes a small but usually continuous flow of water. Figure 16 illustrates the typical flows from the hydrogenation area over a typical 24 hour period. Table 2 illustrates the concentrations of contaminants from this area.

TABLE 2

CONTAMINANT FROM HYDROGENATION AREA IN PPM

	ETHER SOLUBLES	BOD	COD	SUSPENDED SOLIDS
Average	300	400	1000	180
Minimum	165		640	86
Maximum	506		1760	350

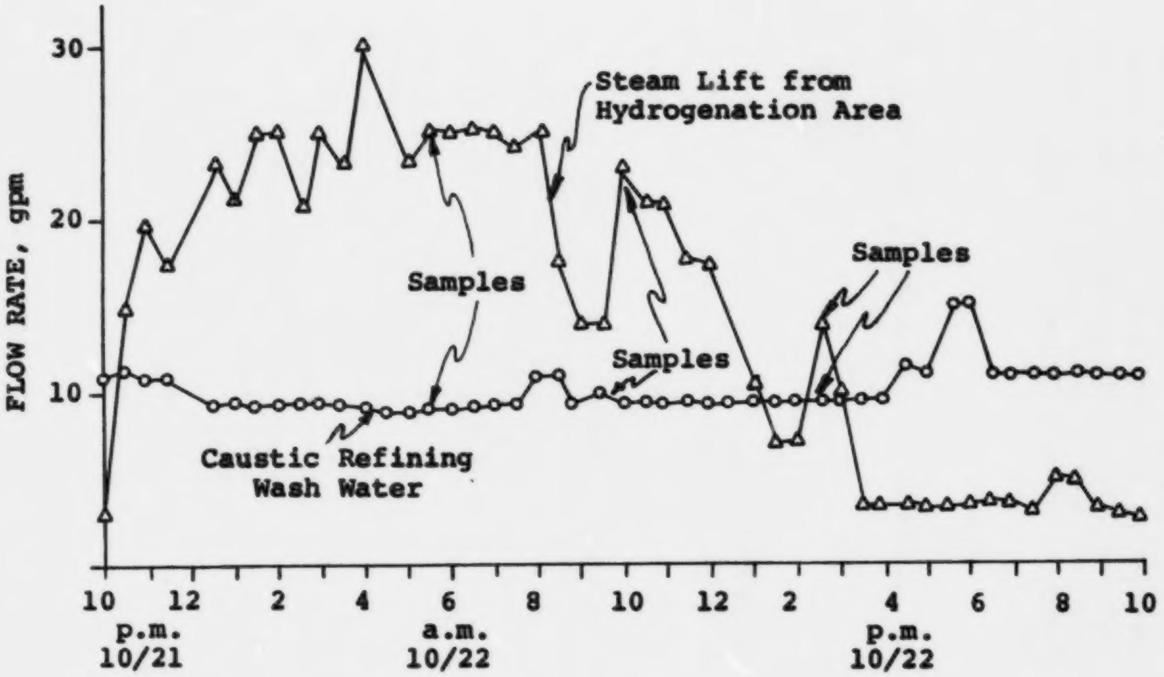


FIGURE 16: SUB-PROCESS FLOW RATES

Deodorization

Oil to be deodorized is pumped from the indoor storage area to one of three deodorizers. These are actually steam stripping chambers for the removal of fatty acids. Fatty acids are recovered in condensers and pumped to the outdoor tank farm for sale. There is an intermittant flow of water (Stream A, Figure 14) from the condenser amounting to 10 to 15 gallons during 10 to 15 seconds of each minute. It has the following average characteristics, based on 6 grab samples.

TABLE 3

AVERAGE CHARACTERISTICS OF DEODORIZER CONDENSATE WATER IN PPM

ETHER SOLUBLES	BOD	COD	SUSPENDED SOLIDS
555	440	940	408

The relatively clean deodorizer condensate water flows through an overload pipe into the hot well sump.

Indoor Tank Farm

Transfer of the various types and quantities of oils involves the large storage tanks in the banked indoor tank farm. The major sources of waste water from this area are the erratic flows due to washing and cleaning processes to remove oils and greases that accumulate due to leaks, transfer operations, pump failures, etc. The total flow and contaminant load from this area, plus that from cleaning operations in the caustic refining, bleaching and hydrogenation areas, are shown as Stream G in Figure 14.

The individual flows from each area comprising stream G were estimated based upon the typical usage of cleaning hoses. Excavating through concrete floors to expose individual sewers was not considered practical or necessary. On this basis, flow from the indoor tank farm, hydrogenation, bleaching and caustic refining areas averaged 50, 35, 20, and 15 gpm, respectively.

Overall Waste Water

The combined overall industrial process waste stream is shown as Stream H in Figure 14. Full details of flow and composition are given in Section VI, Table 15.

Milk Room, Production Pack and Fill, Remelt Areas

These production areas and machinery are thoroughly cleaned during the midnight shift and this constitutes the major hydraulic and contaminant load during this 8-hour period (Stream B, Figure 14). Figures 17 and 18 illustrate the variations in flow and contaminant load that can be experienced during this period. Flow measurements were made using a conductivity technique described in Appendix B, Section XII. here again, the flows comprising Stream B flow through underground sewers. The individual flows were estimated, based upon typical hose usage, to average 20, 60, and 20 gpm for the milk room, production pack and fill, and the remelt areas, respectively.

PLANT EXTERIOR

Outdoor Tank Farm

This area consists of tanks used for the storage of raw edible vegetable oils and tallows. The area is banked to prevent major oil spills reaching past the tank farm area. The area also contains cone tanks for the dewatering of inedible oils that have been removed from the waste stream or from the reclaim area. The major water wastes from this area are the water drawn from the cone tanks and the condensate water from the oil heating operations.

Tank Car Washing

The tank car washing area is adjacent to the outdoor tank farm but is unbanked so that spills that may occur usually run into the diversion box area and thus end up in the waste stream. An average of 10 tank cars a week are washed and this usually occurs during the day. Figure 19 illustrates the flows and concentrations from the combined flow of the outdoor tank farm and the tank washing area (Stream F, Figure 14) after one tank car has been washed. A holding tank is used to retain the bulk oil flushed out of the tank car. This oil is then pumped to the inedible oil holding section of the outdoor tank farm.

The individual flows comprising Stream F flow through common underground sewers, and based upon typical hose usage, were estimated to average 27 and 20 gpm for the tank car wash and outdoor tank farm areas, respectively.

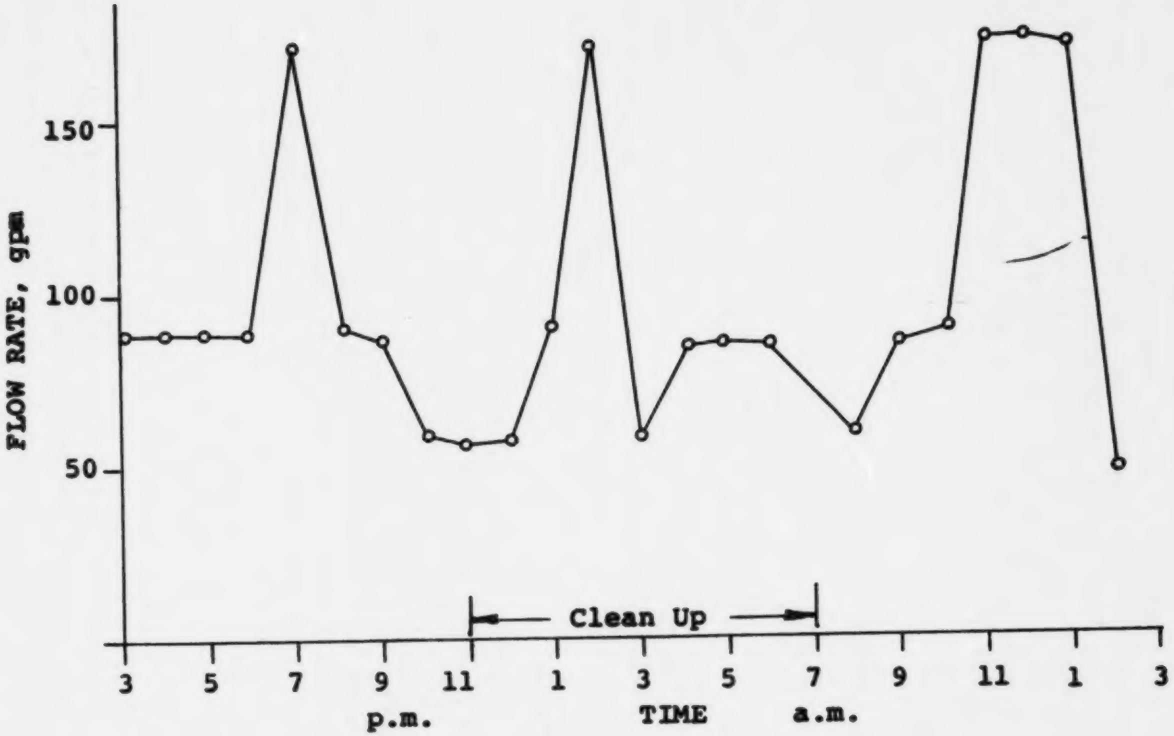


FIGURE 17: MAIN PROCESS SEWER FLOW RATES

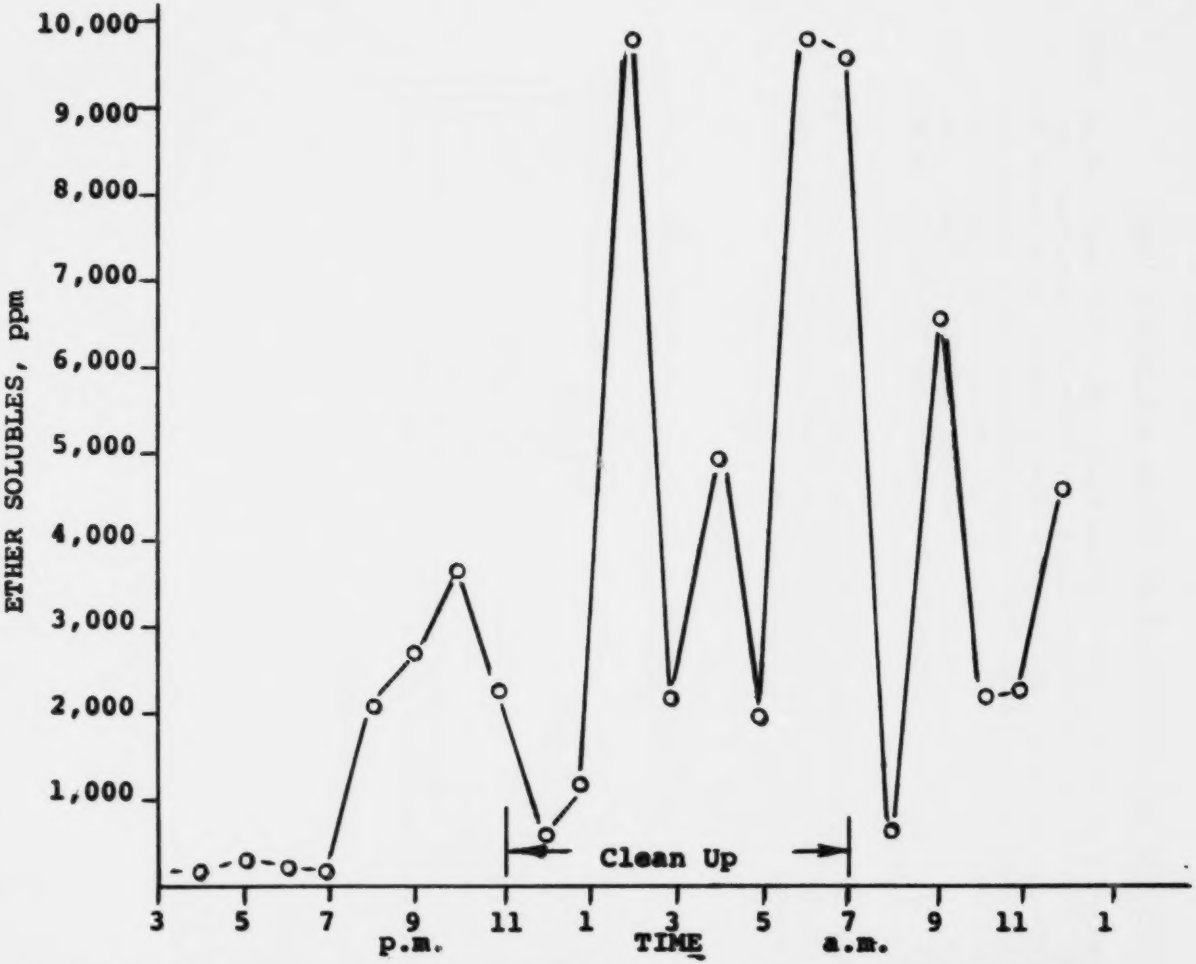


FIGURE 18: ETHER SOLUBLE CONCENTRATIONS IN MAIN PROCESS SEWER

Relationships Between Production and Waste Load

Twenty-four hour plant production data for each major area were subjected to statistical regression analyses to determine relationships with plant waste flow rate and contaminants loading. No correlations were found for individual production areas, or grand total production. This is consistent with the survey results which show that most of the waste results from general cleaning indoors and outdoors.

Table 4 gives average and range production data for each production area in thousands of pounds per 24-hour day, covering 42 days of operations.

TABLE 4

PRODUCTION DATA FOR BRADLEY REFINERY

PRODUCTION AREA	PRODUCTION, 1000 lb/24 hr	
	AVERAGE	RANGE
Caustic Refining[a)]	541	265-990
Hydrogentation	290	165-385
Bleaching	630	270-980
Deodorizing	815	601-946
Shortening Manufacturing	552	449-661
Margarine Manufacturing	156	92-205

a) All oils processed.

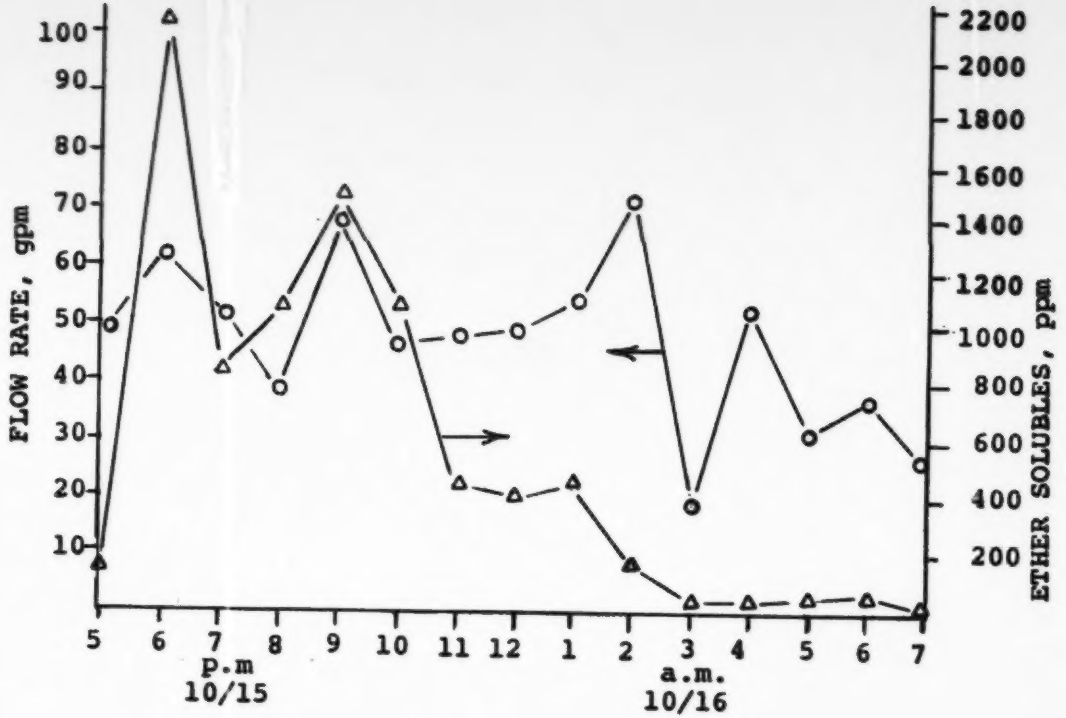


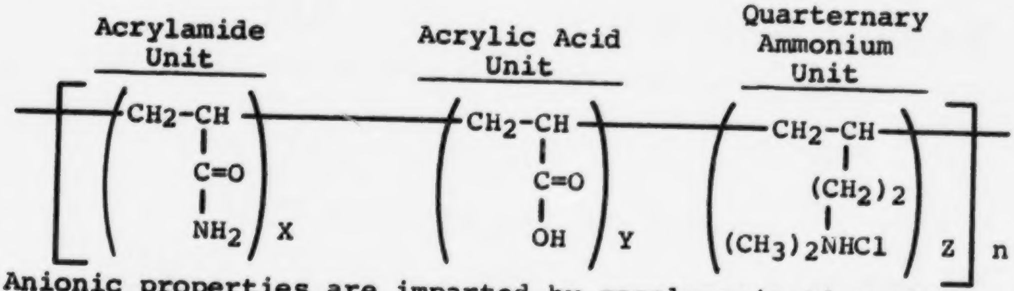
FIGURE 19: ETHER SOLUBLES AND FLOW RATE OF COMBINED OUTDOOR TANK AND TANK CAR WASHING AREAS

SECTION VI

EVALUATION OF FLOCCULANTS

The purpose of this part of the overall study was to evaluate the effectiveness of a variety of synthetic polyacrylamides, readily available commercially from Swift or others before this project, in combination with alum and other such coagulants. In general, coagulants such as alum produce a pinpoint sized particle. The role of the polymer is to produce a further agglomeration of these pinpoint particles to a size that will be more amenable to separation.

All polymers tested were polyacrylamides and derivatives thereof. A typical structural formula is given below:



Anionic properties are imparted by copolymerization with acrylic acid, with the carboxylic acid group of acrylic acid serving as a center of negative charge. Cationic properties can be imparted by quarternary ammonium compound copolymerization, in which the quarternary nitrogen serves as a center of positive charge.

When alum is added to a waste water, it reacts with the alkalinity of the water producing a voluminous flocculent precipitate. The following represents this reaction:

$$Al_2(SO_4)_3 + 3Ca(HCO_3)_2 = 3CaSO_4 + \underline{2Al(OH)}_3\downarrow + 6CO_2 \quad \text{(Eq. 1)}$$

Actually in practice the mechanism is more complex involving five distinct actions:

1. A chemical reaction occurs similar to the above which results in formation of a gelatinous amphoteric precipitate, aluminum hydroxide hydrate, which acts either negatively or positively, in this case positively because of the negatively charged surroundings.

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2. Colloidal particles in the water are negatively charged and repel each other. The positively charged aluminum ion from alum reduces these charges and permits coagulation.

3. The aluminum ion from alum reacts with soaps, saponified fats, and surfactants producing a less soluble material with lower emulsifying properties.

4. Collodial particles are adsorbed by the flocs.

5. Suspended particles are physically entrapped.

First, laboratory screening tests were performed on seven polymers in combination with alum and some other coagulants. Then four of these polymers were selected and evaluated in the full Bradley Waste Treatment System. Analytical procedures are described in the Appendix A, Section XII.

LABORATORY SCREENING TESTS

The following polymers were screened in the laboratory tests:

TABLE 5

POLYMERS USED IN LABORATORY TESTS

Polymer No.	Name	Charge
1	Nalco 673	Nonionic
2	Dow NP-20	Nonionic
4	Swift X-400	Anionic
5	American Cyanamid P-250	Nonionic
6	Swift X-111	Cationic
7	Swift X-420	Anionic
8	Swift X-700	Nonionic

The first study of the experimental laboratory screening program consisted of comparing the above polymers with three coagulants (alum, zinc chloride, and ferric sulfate) and three initial pH levels (9.5 ambient, 7.0, and 5.0 as adjusted with sulfuric acid before chemicals addition). No buffer was used for these or later described laboratory tests in order to simulate intended field treatment. After flocculation and flotation of the oil phase, the turbidity of the clarified water was measured in JTU's (Jackson Turbidity Units) at 30 seconds and 2 minute intervals. The Jackson Turbidity Units were determined on a direct reading Hellige Turbidometer. Typical Bradley plant waste effluent, representing a 48-hour composite sample, was treated in 100 milliliter graduates. After the addition of the coagulant, the graduates were shaken 20 times to simulate air flotation conditions, followed by gentle inversion (5 times) after the addition of the polymer. At 30 second and 2 minute intervals the clarified portion was removed and read in the Hellige cell.

The composite sample used for this study had the following analysis: Total Solids - 4,227 ppm; Suspended Solids - 3,152 ppm; Ether Solubles - 2,736 ppm; and pH - 9.5.

The test data of this study were subjected to statistical analysis with the following results at 95% confidence level:

1. Zinc chloride and alum are both better than ferric sulfate. Zinc chloride was better than alum. Their relative performances are compared in Table 6 on the basis of average turbidity of the clarified water sample.

TABLE 6

COMPARISON OF DIFFERENT COAGULANTS (ALL LEVELS)

Coagulant	Mean JTU
Zinc chloride	574
Alum	609
Ferric Sulfate	643

2. Under all conditions, the highest level of coagulant used (500 ppm) was most effective at reducing turbidity:

TABLE 7

COMPARISON OF COAGULANT LEVEL

Coagulant	Mean JTU
0 ppm	680
50 ppm	643
100 ppm	615
500 ppm	501

3. Polymer, in conjunction with 100 ppm or more of coagulant, significantly lowered turbidity:

TABLE 8

GENERAL EFFECT OF POLYMER ADDITION AT VARIOUS COAGULANT LEVELS

	Mean JTU for Coagulant Level, ppm of:			
Polymer Level	0	50	100	500
0 ppm	678	640	647	533
2.5 ppm	681	647	579	462

4. Anionic and nonionic polymers generally performed better than the single cationic tested, especially at lower pH levels:

TABLE 9

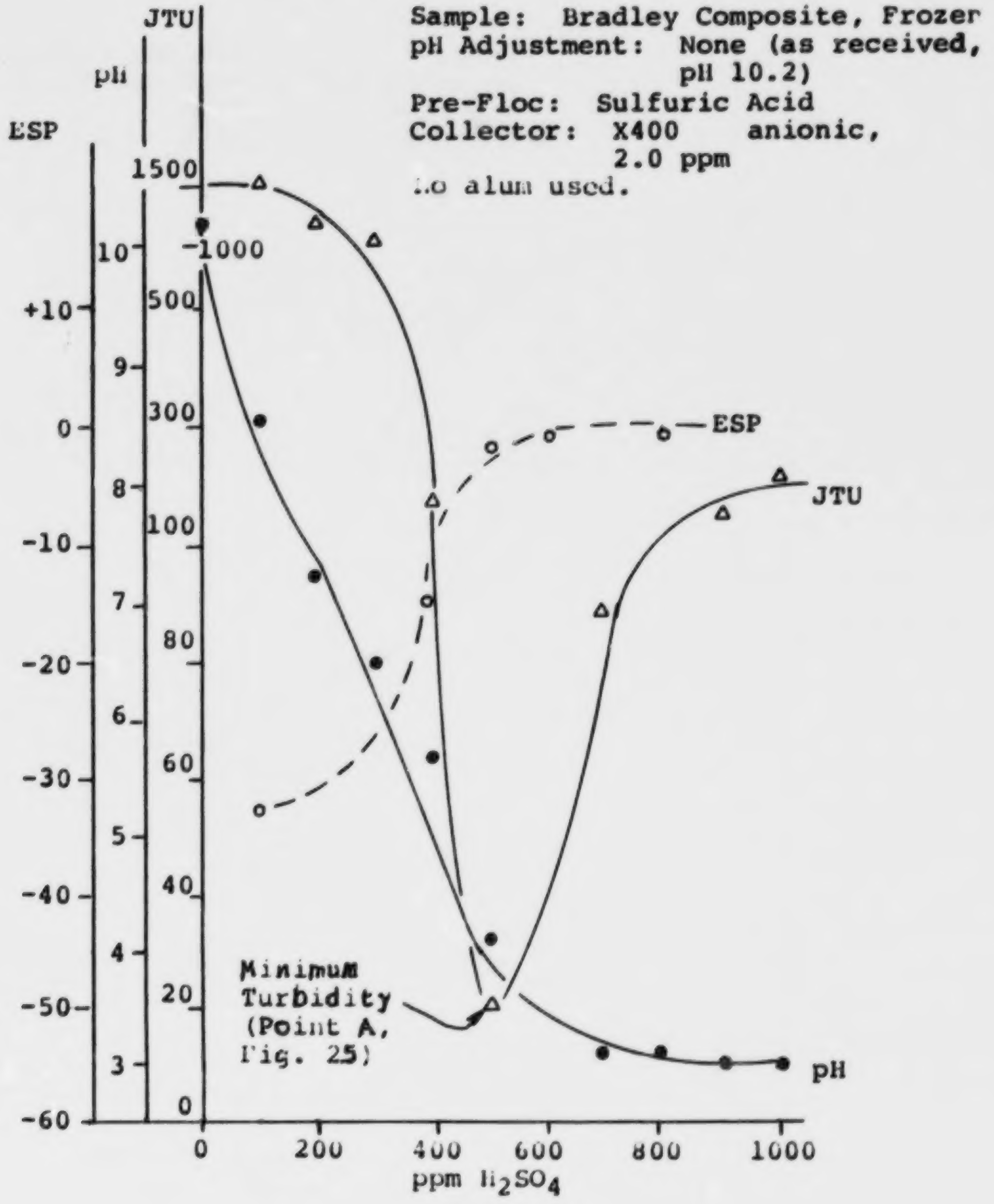
COMPARISON OF DIFFERENT POLYMER SYSTEMS (RANKED IN ORDER OF PERFORMANCE)

Polymer No.	Name	Charge	Mean JTU
4	Swift X-400	Anionic	521
8	Swift X-700	Nonionic	571
5	American Cyanamide P-250	Nonionic	591
2	Dow NP-20	Nonionic	593
1	Nalco 673	Nonionic	601
7	Swift X-420	Anionic	646
6	Swift X-111	Cationic	685

Additional laboratory screening studies were conducted in which the relationships between surface charge, pH, and turbidity were further investigated. The procedure used a 48 hour composite effluent sample, different from the one used above, with the following analyses: Total Solids - 8,168 ppm; Suspended Solids - 5,694 ppm; Ether Solubles - 5,391 ppm; BOD - 9,120 ppm; and pH - 10.2. It was treated with varying amounts of sulfuric acid and alum, after which 2.0 ppm of Swift X-400 polymer was added to effect final flocculation. The graduate cylinder method was used was in the first study. The Effective Surface Potential (ESP) was determined on a Water Associates' Streaming Current Detector. The pH was determined using a Leeds & Northrup meter.

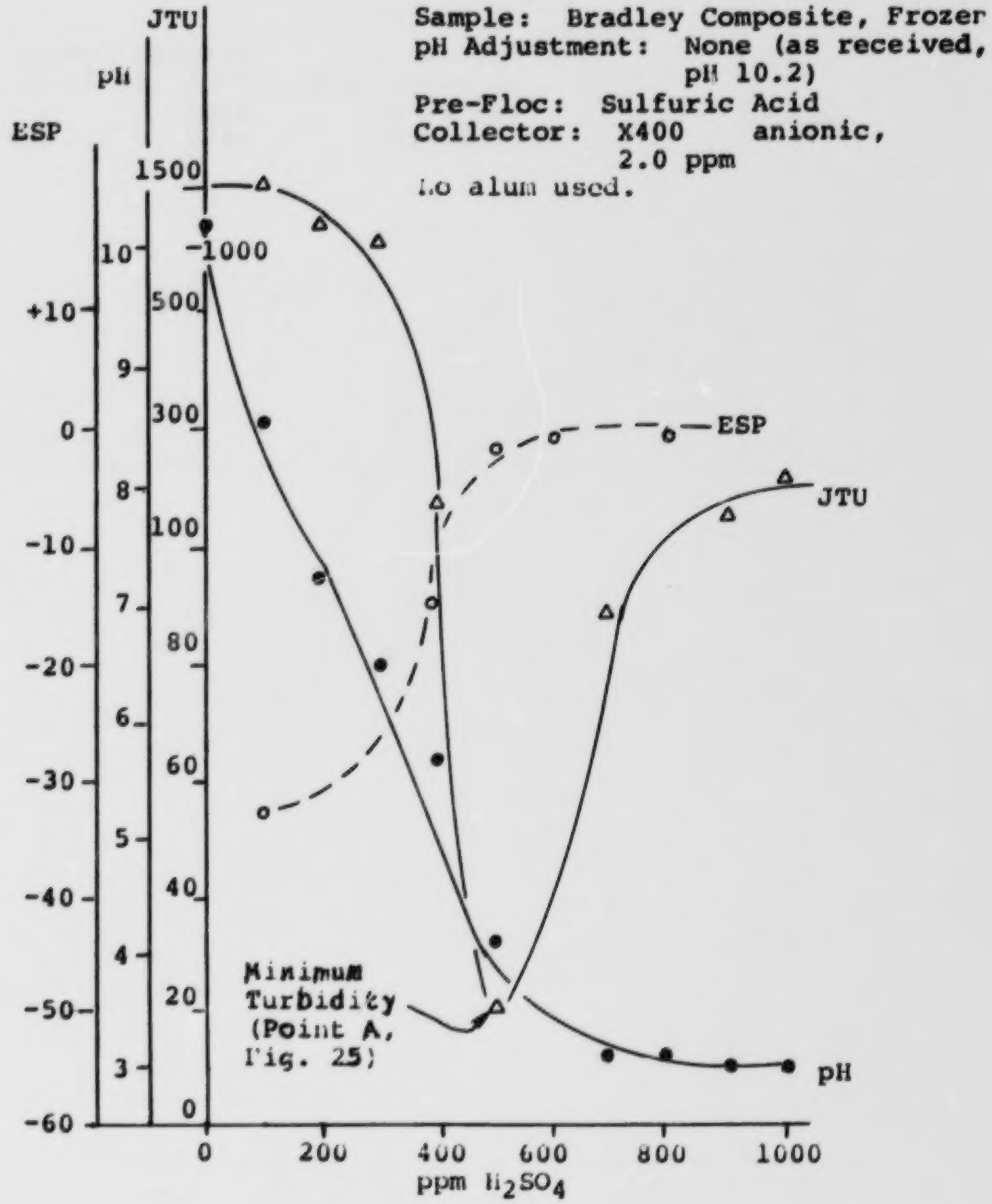
The results of this study are summarized in Figures 20 through 24. The data suggests that sulfuric acid alone acts as an effective pre-floc agent for coagulant aid at pH 4 as illustrated in Figures 20 and 24. All the Figures suggest that, as expected, the alum required to achieve maximum clarity was reduced as the pH was lowered.

The Figures also show that the point of maximum clarity (or minimum JTU) appears as the ESP approaches zero, but is not necessarily maintained even though the EPS may remain near zero as the curves move from left to right, or in the direction of increasing the alum dosage. This suggests that a zero particle charge is not necessarily associated with optimum solids removal through flocculation. It is also seen, in general, that the point of maximum clarity is often rather sharply defined, particularly in the mid-alum dosage and pH ranges. The data suggests an optimum pH exists for any given condition of flocculation.



Sample: Bradley Composite, Frozer
pH Adjustment: None (as received, pH 10.2)
Pre-Floc: Sulfuric Acid
Collector: X400 anionic, 2.0 ppm
No alum used.

FIGURE 20: EFFECTS OF INITIAL pH AND ACID DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY, AND EFFECTIVE SURFACE POTENTIAL



Sample: Bradley Composite, Frozen
pH Adjustment: None (as received,
pH 10.2)
Pre-Floc: Sulfuric Acid
Collector: X400 anionic,
2.0 ppm
No alum used.

FIGURE 20: EFFECTS OF INITIAL pH AND ACID DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY, AND EFFECTIVE SURFACE POTENTIAL

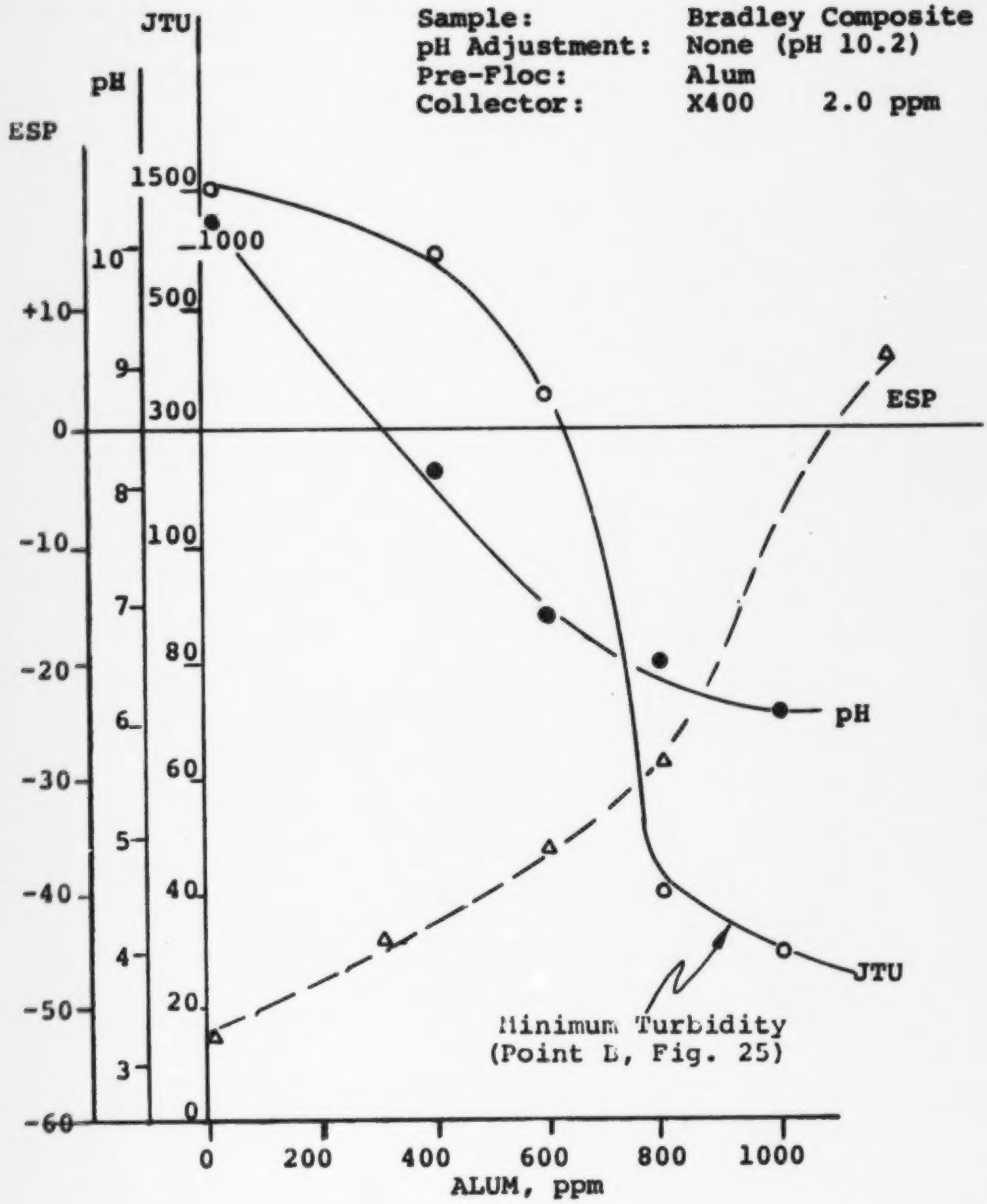
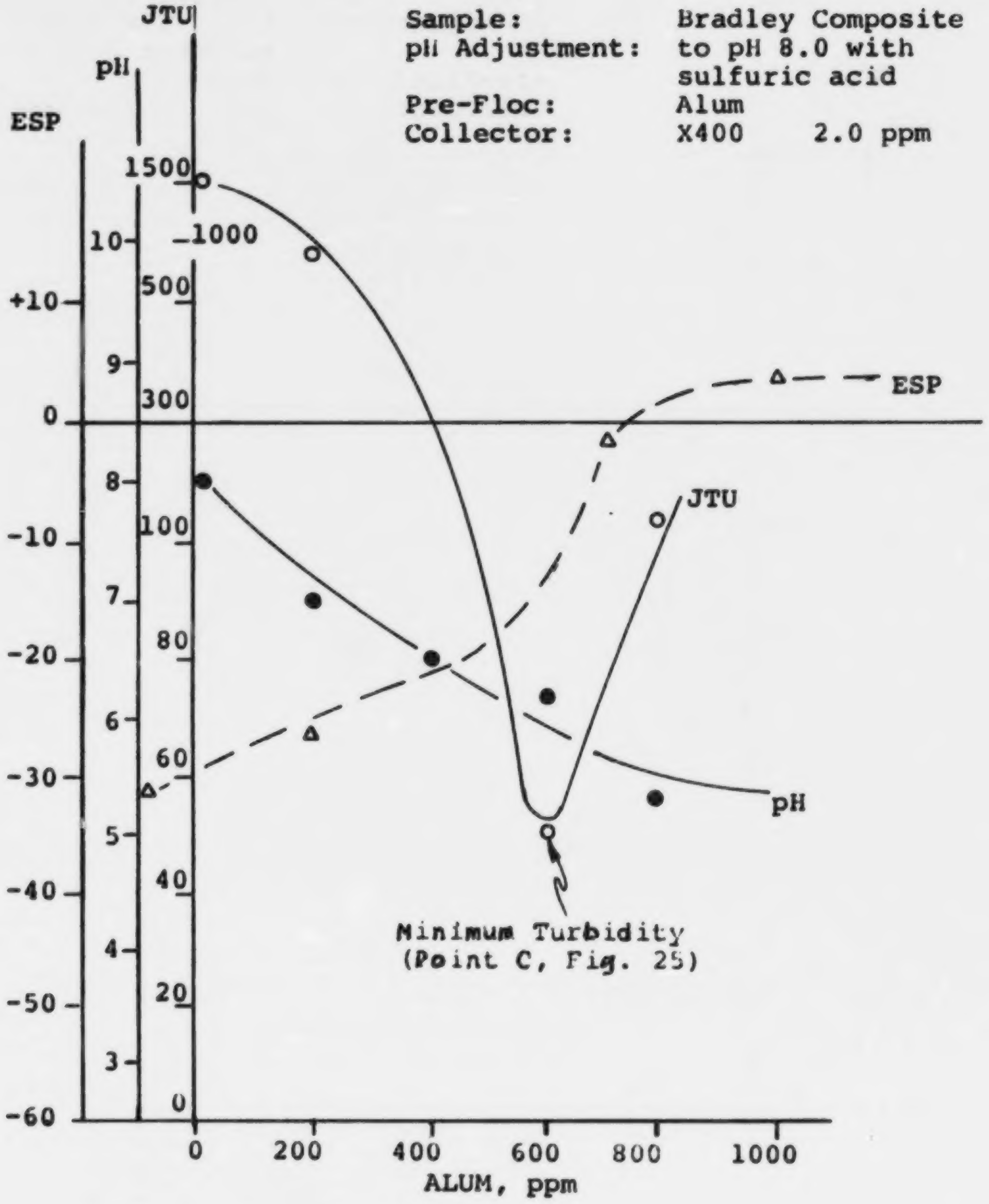


FIGURE 21: EFFECTS OF INITIAL pH AND ALUM DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY, AND EFFECTIVE SURFACE POTENTIAL



Sample: Bradley Composite
pH Adjustment: to pH 8.0 with sulfuric acid
Pre-Floc: Alum
Collector: X400 2.0 ppm

Minimum Turbidity
(Point C, Fig. 25)

FIGURE 22: EFFECTS OF INITIAL pH AND ALUM DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY, AND EFFECTIVE SURFACE POTENTIAL

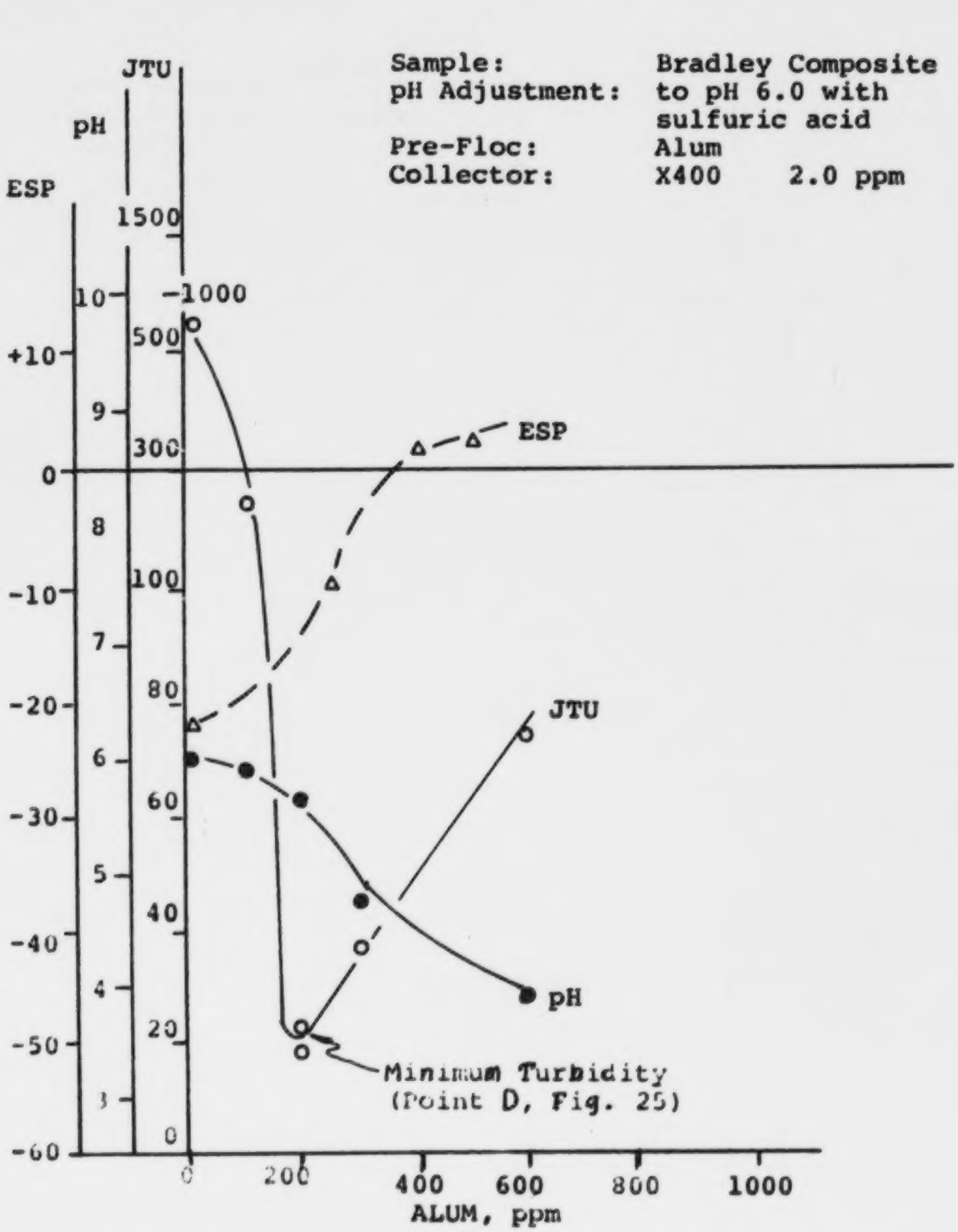


FIGURE 23: EFFECTS OF INITIAL pH AND ALUM DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY AND EFFECTIVE SURFACE POTENTIAL

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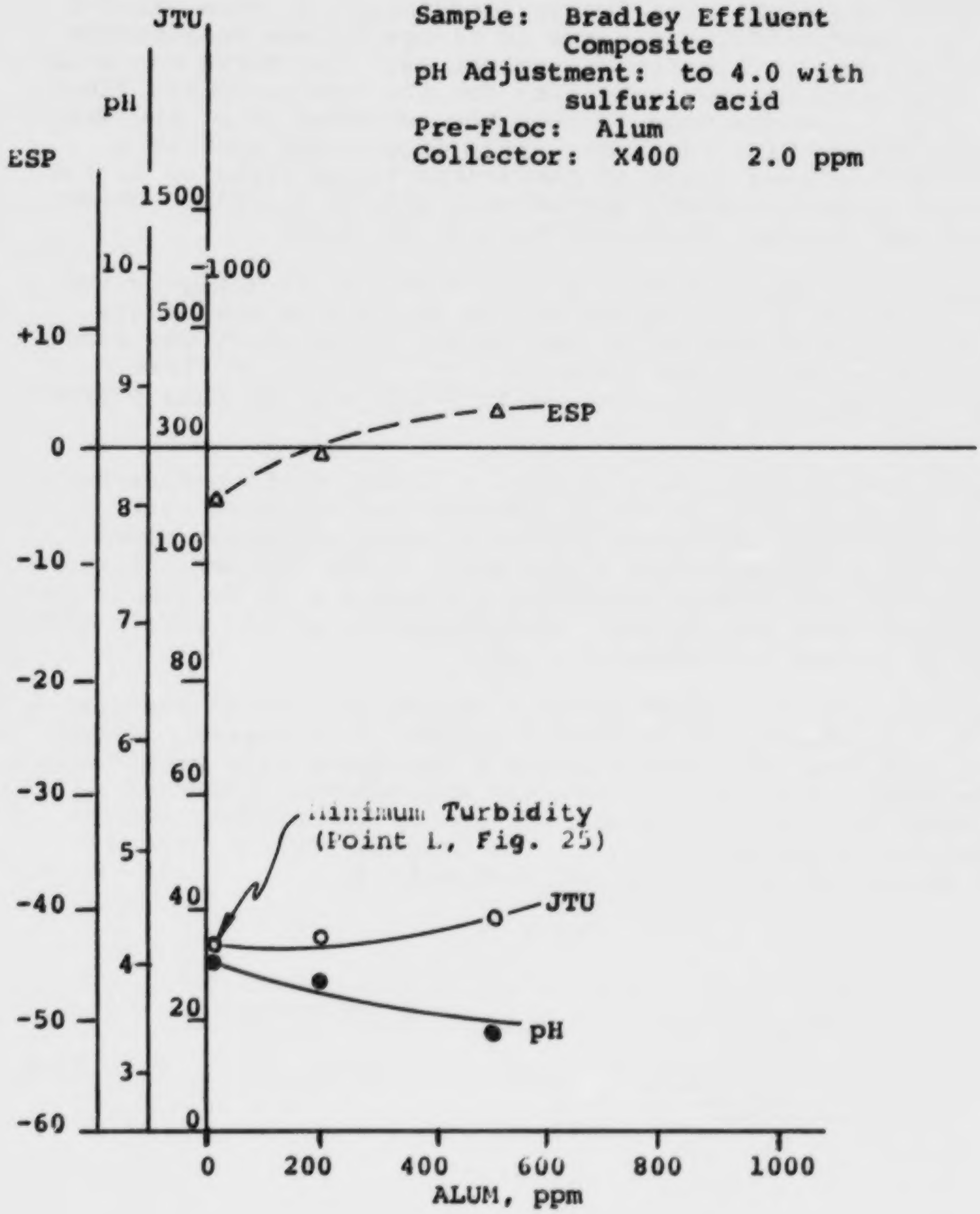

FIGURE 24: EFFECTS OF INITIAL pH AND ALUM DOSAGE ON CLARIFIED PHASE FINAL pH, TURBIDITY, AND EFFECTIVE SURFACE POTENTIAL

Minimum Turbidity Curve

To summarize the relationships between initial and acid adjusted waste pH, alum dosage, and final pH, when using 2 ppm of Swift X-400, the curve in Figure 25 was constructed from the data in Figures 20 through 24. The curve connects all points of minimum turbidity for the corresponding final pH. Tie lines are used to show the adjusted pH of the waste sample before alum addition. This figure was used as a guide to the best range of conditions to be explored in the Bradley waste treatment system evaluations described below under the heading "Bradley Flocculation Tests".

Another laboratory study was undertaken to investigate the use of sodium aluminate and ferric sulfate as coagulants. Again, the same sample as used in the first study was used. The test procedure was comparable to that in the first study, except that 2 ppm of Swift X-400 was the only polymer utilized.

The waste water had been held in a frozen state before being used for this study. 100 cc samples were treated with varying amounts of either ferric sulfate or sodium aluminate, shaken 15 seconds, 2 ppm Swift X-400 polymeric flocculant added and mixed, and after 3 minutes a 25 cc sample was withdrawn from the bottom. The turbidity of the sample was read on a Hach Turbidimeter.

Previous work had shown that as the pH is lowered towards pH 4, the removal of suspended solids is increased. Treatment with both of these chemicals confirmed this previous knowledge. The sodium aluminate was not too effective because its addition raised the pH and increasing amounts resulted in poorer clarity. The data in Table 10 illustrates the effect of the two chemicals.

TABLE 10

USE OF FERRIC SULFATE AND SODIUM ALUMINATE FOR FLOCCULATING BRADLEY WASTE WATER

Initial pH	ppm Chemical	Final pH	Turbidity
Ferric Sulfate			
9.5	1,000	4.5	14 JTU
9.5	750	4.8	24
9.5	500	5.3	30
8	750	3.7	15
8	500	5.3	30
8	250	7	630
6	500	4.3	14
6	250	5.3	115
6	100	5.8	450
4	100	3.6	21
4	50	3.9	27
4	0	4	50

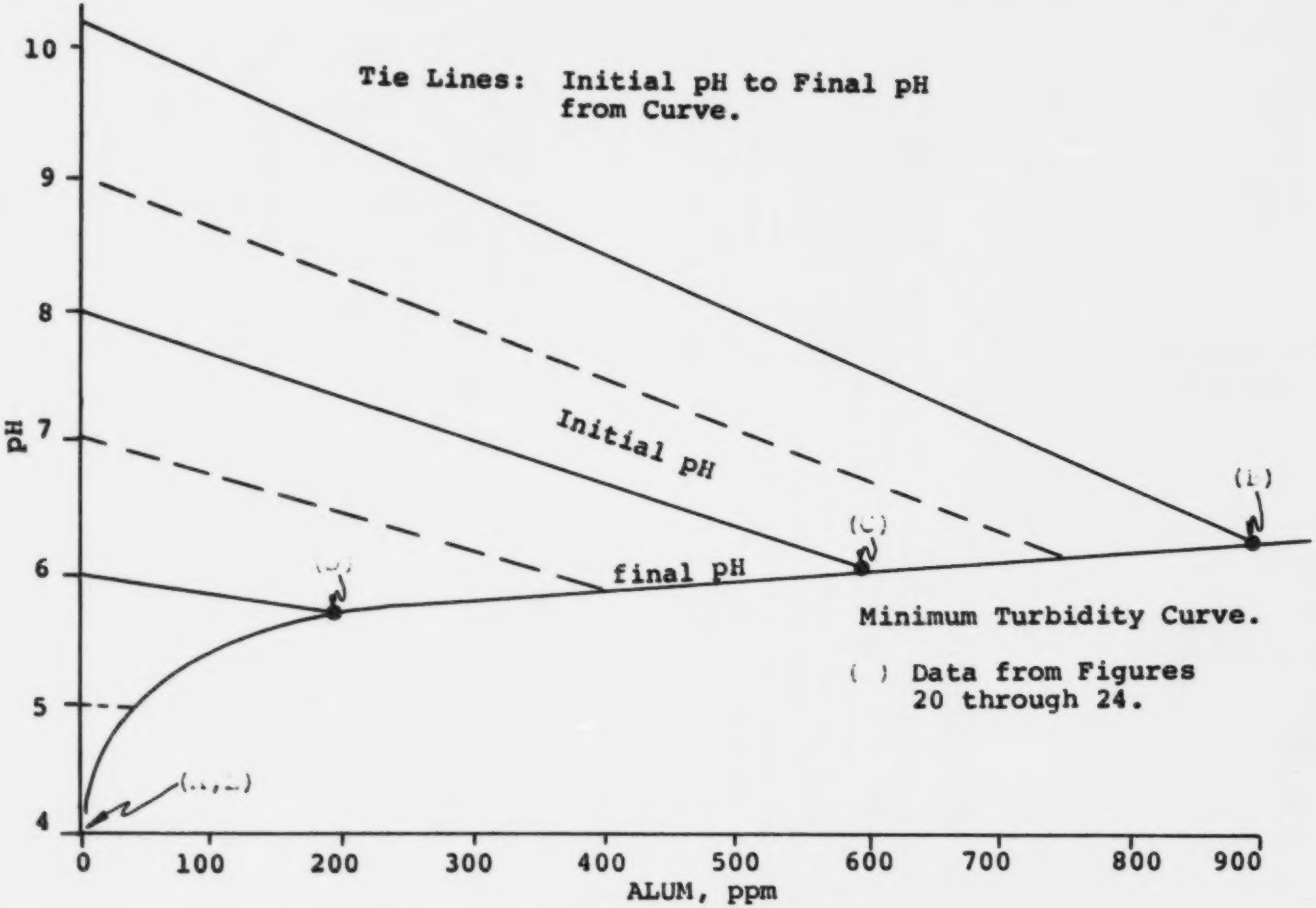

FIGURE 25: MINIMUM TURBIDITY CURVE; AND INITIAL pH, FINAL pH, AND ALUM DOSAGE REQUIRED

TABLE 10 (Continued)

Initial pH	ppm Chemical	Final pH	Turbidity
Sodium Aluminate			
9.5	1,000	9.7	900 JTU
9.5	500	9.5	600
9.5	100	9.5	440
8	1,000	9.5	830
8	100	8.8	750
6	500	9.3	630
6	100	7.2	520
6	50	6.9	300
4	100	6.6	77
4	50	5.8	35

BRADLEY FLOCCULATION TESTS

Based upon the laboratory screening tests above, four polymers were selected for field evaluation, namely: Swift X-400, American Cyanamid P-250, Dow NP-20, and Nalco 670. Nalco 670 was used rather than the 673 since it was more readily available and was considered even more effective. Except for brief tests with ferric sulfate, alum was used exclusively as the coagulant. Zinc chloride was not used because of concern over potential toxicology questions. Sodium aluminate was not used because of the negative laboratory screening tests.

General Procedure

The tests were set up on a shift basis. Dosages of alum and polymer were held as nearly constant as possible during an entire shift. Alum at 20% solution concentration was metered into the Air Flotation Cell supply about 20 feet upstream from the inline mixer. Polymer at 0.2% solution concentration was added immediately after the back pressure valve between the pressure retention tank just ahead of the Air Flotation cell. The manually adjusted Milton Roy metering pumps for the alum and polymers were set at rates corresponding to the total waste in-put flow rates as measured by the magnetic flow meter in order to maintain the desired dosage levels. Concentrated sulfuric acid was added either manually or automatically into the chemical mix loop ahead of the Skim unit to adjust the pH of the raw waste to desired livels. The aforementioned Figure 25 was used to select the adjusted raw waste pH corresponding to that alum dosage which would be expected to yield maximum treated effluent clarity. In other words, in the field tests an attempt was made to follow the optimum pH-alum curve, rather than a random experimental approach. This approach was necessary to maintain generally good system performance because all of the waste from the plant was being treated and effluent quality had to be maintained at acceptable levels whenever possible.

Four levels of alum were used, typically 100, 300, 500 and 700 ppm. Two levels of polymer addition were used, 2 and 4 ppm. Finally, the alum dosage was maintained constant over three shifts and the polymer was changed from shift to shift. The pH's were varied accordingly. Typically, the recovered skimmings were collected over a 24-hour period and then were treated through the centrifuge as described later. Typically, one week was required to test a single polymer through the above schedule. Each polymer was tested essentially one week at a time, in this fashion, and then a second round was conducted. In all, 184 shifts of data were obtained.

Samples of the raw plant waste, effluent from the Skimmer, and effluent from the Air Flotation cell were collected every two hours, i.e. four samples per shift. Then these four individual samples for each stream were composited into a single shift sample. Equal volumes for each of the four 2-hour samples were used.

Complete system raw operating data was recorded each hour by technicians and the plant waste treatment system operators. The resultant operating data (after basic calculations), along with analytical results, are given in Table 24 in Appendix C, Section XII.

During the entire period the cathodic protection devices were in operation at standard conditions.

Major Results

The following were the major results. Details are given in subsequent paragraphs.

1. The polymers all generally performed about equally at all dosages used. No more than 2 ppm need be used as a practical matter.

2. Best results were achieved for both the Air Flotation cell and the Skim tank when the final Air Flotation pH was in the range of 3.5 to 6.0.

3. Concerning the Air Flotation cell, good results generally were obtained at all alum dosages ranging from 100 to 700 ppm, provided the pH of the stream was consistent with the 3.5 to 6.0 range. Brief tests with ferric sulfate showed that, although results were good and required perhaps somewhat less dosage compared to alum, considerable difficulty was experienced in putting the ferric sulfate into solution and in handling the large amount of sludge remaining in the solution through the pumps. Of more importance, the ferric sulfate colored the resultant recovered oil red.

4. In spite of broad variations in the raw waste composition, pH, and flow rate, the system performed well on an overall average basis, consistent with original projections. However, the Bradley system, given the present waste load, is substantially undersized to produce a waste consistently under 400 ppm of all contaminants, particularly BOD.

5. It is believed that the data contained herein would facilitate calculation and determination of the appropriately designed new system equipment or, in the case of Bradley, the addition of a second Air Flotation cell to arrive at a plant waste effluent of any desired final composition.

Regression Analyses

Regression analyses were performed on all of the data to determine the effect of pH, stream contaminant composition, temperature, flow rate, and alum and polymer type and dosage (where applicable) on the quality of the effluent from the Skim tank and Air Flotation cell, and the percent removal of each contaminant component. The regression data at the 90% confidence limit or above for the Skim unit are summarized in Table 11, and for the Air Flotation cell in Table 12. In Table 11 is an example showing how the regression coefficients can be used to estimate or predict the Skimmer and Air Flotation effluent compositions knowing the values for the respective influent composition, pH, temperature, and so on.

For the Skim unit, the correlations obtained are fair, with pH, input contaminent concentration, and temperature controlling Skimmer effluent quality. Performance was generally independent of flow rate.

For the Air Flotation unit, none of the input variables except ether solubles concentration yielded useful correlations with effluent quality. It is felt that this general lack of good correlation is due largely to (1) the basic ability of the system to handle the waste load, and (2) the fact that pH, alum, and polymer levels were maintained as much as possible within the ranges needed to provide good operation, i.e. in accordance with Figure 25.

Other regression correlations were developed relating BOD with the ether solubles and suspended solids content for the raw waste (Table 13), Skimmer effluent (Table 13), and Air Flotation effluent (Table 14). For the latter, turbidity was also correlated with ether solubles, suspended solids, and BOD. These correlations support the obvious, that BOD and turbidity depend on ether solubles and suspended solids content but the accuracy of prediction is low.

TABLE 11: SKIMMER UNIT

Regression Coefficients for Variables Significant at the 90% Confidence Level or Above[a)]

Effluent Dependent Variable	Intercept	(3)[b)] Waste gpm	(21) Effluent pH	(12,14,16) Contaminant Load, ppm	(43) Temp °F	$(21)^2$ pH Sq'd	Std[c)] Error	R^2[d)]
(22) Sus. Solids,ppm	-5977		+211.	+.49	+46.		1940.	42%
(24) Sus. Solids, % removed	+ 167.			+.0021	- 1.09	-.51	47.	12%
(25) Ether Sol., ppm	-5378.		+232.	+.48	+38.		1829.	28%
(27) Ether Sol, % removed	234.	- .10		+0033	- 1.43	-.39	46.	10%
(28) BOD,ppm	-5912.	+3.	+172.	+.41	+44.		1320.	40%
(30) BOD, % removed	19.		- 3.72	.0072			56.	9%

a) For example, Skimmer effluent suspended solids, ppm, can be estimated as follows: Eff. Sus. Solids, ppm = -5977 + 211 (Eff. pH) + .49 (Influent Sus. Solids, ppm) + 46 (Temp, °F) ± 1.65 (1940) for 90% confidnece.

b) Numbers in ( ) are data column references in Table 24.

c) Confidence ranges on predicted values may be calculated by multiplying standard prediction errors by ± 1.96, ± 1.65, and ± .68 for 95%, 90%, and 50% confidence levels, respectively.

d) R is the regression equation correlation coefficient. R^2 is the proportion (here expressed as a percentage) of the total variation in the dependent variable that has been accounted for by use of the regression equation.

TABLE 12: AIR FLOTATION UNIT

Regression Coefficients for Variables Significant at the 90% Confidence Level or Higher[a]

Effluent Dependent Variable	Intercept	(6) Alum ppm	(7) Poly ppm	(5) Waste gpm	(22)[b] Influent Sus.Solids ppm	(31) Effluent pH	$(31)^2$ pH Sq'd	(43) Temp °F	Std[c] Error	R^2
(32) Sus. Solids,ppm	+432.				+.02				595.	2%
(34) Sus. Solids % removed	+ 16	-.14		+.27	+.0049				133.	8%
(41) Turbidity	-653.						+7.69	+7.04	342.	13%

Effluent Dependent Variable	Intercept	(5) Waste gpm	(6) Alum ppm	(7) Poly ppm	(25) Influent Ether Sol. ppm	(31) Effluent pH	$(31)^2$ pH Sq'd	(43) Temp °F	Std Error	R^2
(35)Ether Sol.,ppm	+1041.				+.0107		+36.		402.	17%
(37)Ether Sol., % removed	-123.	+.1054			+.0018			+1.29	40.	14%
(41) Turbidity	-653.						+ 8.	+7.	339.	15%

a) See sample calculation, Table 11, footnote (a)

b) Numbers in ( ) are data column references in Table 24.

c) See note (c) in Table 11.

TABLE 13

REGRESSION COEFFICIENTS[a] AMONG ANALYSES ON RAW WASTE AND SKIM UNIT EFFLUENT[b]

Dependent Variable	Intercept	(12)[c] Waste Sus.Solids ppm	(14) Waste Ether Sol. ppm	(22) Skim Unit Sus.Solids ppm	(25) Skim Unit Ether Sol. ppm	Std[d] Error	R^2
(16) Raw Waste BOD, ppm	+2829.	+.2274				2159.	17%
(16) Raw Waste BOD, ppm	+3302.		+.0849			2275.	8%
(28) Skim Unit BOD, ppm	+2118.			+.1873		1529	22%
(28) Skim Unit BOD, ppm	+2234.				+.1300	1574.	17%

a) Simple regression coefficients. Inclusion of both suspended solids and ether solubles in the regressions did not improve the correlations.

b) See sample calculation, Table 11, footnote (a)

c) Numbers in ( ) are data column references in Table 24.

d) See footnote (c) in Table 11.

TABLE 14

REGRESSION COEFFICIENTS[a] AMONG ANALYSES FOR AIR FLOTATION UNIT[b]

Effluent Dependent Variable	Intercept	(32)[c] Effluent Sus.Solids ppm	(35) Effluent Ether Sol. ppm	(38) Effluent BOD, ppm	(41) Turbidity	Std[d] Error	R^2
(41) Turbidity	+261.		+.3038			394.	13%
(41) Tur bidity	+246.	+.3044				396.	11%
(41) Turbidity	+148.			+.2357		306.	32%
(38) BOD	+216.		+1.578			546.	62%
(38) BOD	+464.	+7572				754.	27%
(38) BOD	+361.				+1.364	735	32%

---

a) Simple regression coefficients. Inclusion of both suspended solids and ether solubles in the first, second, fourth and fifth regressions above did not improve the correlations.

b) See sample calculation, Table 11, footnote (a).

c) Numbers in ( ) are data column references in Table 24.

d) See footnote (c) in Table 11.

TABLE 15

AVERAGES, ALL DATA, BY SHIFTS, FOR BRADLEY FLOCCULANT TESTS

Variable		Shift	
	1	2	3
Raw Waste			
gal.	157,200	143,322	138,407
gpm	328	299	288
pH	10.1	8.5	9.0
Sus.Solids, ppm	2,917	4,301	3,679
Sus.Solids, lb.	3,832	5,097	4,293
Ether Sol., ppm	3,329	5,122	3,984
Ether Sol., lb.	4,305	5,964	4,525
BOD, ppm	3,194	3,798	4,012
BOD, lb.	4,235	4,512	4,534
Skimmer Effluent			
pH	7.1	6.1	6.5
Sus.Solids, ppm	2,438	1,956	2,706
Sus.Solids, lb.	3,065	2,324	2,892
Sus.Solids,% removed	19.8	54.3	32.6
Ether Sol., ppm	2,522	1,821	3,195
Ether Sol., lb.	3,149	2,144	3,382
Ether Sol.,% removed	26.8	64.0	25.3
BOD, ppm	2,525	2,699	2,439
BOD, lb.	3,357	3,210	2,798
BOD, % removed	20.6	28.7	38.3
Air Flotation Effluent			
Alum, gal.	337	325	297
Polymer, gal.	222	216	205
Alum, ppm	436	464	452
Polymer, ppm	2.33	2.55	2.59
pH	5.4	5.0	5.0
Sus.Solids, ppm	477	559	401
Sus.Solids, lb.	612	680	453
Sus.Solids,% removed	80.1	70.8	84.3
Ether Sol., ppm	434	370	357
Ether Sol., lb.	540	453	396
Ether Sol.,% removed	82.9	78.9	88.3
BOD, ppm	856	880	741
BOD, lb.	1,062	1,037	832
BOD, % removed	68.4	67.8	70.3
Turbidity	375	293	362
Dissolved Oxygen	7.1	7.0	7.3
Temperature	109	110	111
NP-20, % of shift	16.0	15.0	16.0
P250, % of shift	32.0	34.0	28.0
X-400, % of shift	35.0	32.0	35.0
N-670, % of shift	17.0	19.0	21.0
Overall Removals, %			
Sus. Solids	84.0	86.7	89.4
Ether Solubles	87.2	92.4	91.2
BOD	74.9	77.0	81.6

TABLE 16

AVERAGES, ALL DATA, BY POLYMER FOR BRADLEY FLOCCULANT TESTS

Table Column				Polymer		
Ref.No.	Variable	NP-20	P250	X-400	Nalco 670	All
	Raw Waste					
4.	gal.	173,693	145,102	133,816	150,782	146,632
5.	gpm	362	302	276	314	305
11.	pH	9.2	9.3	9.1	9.3	9.2
12.	Sus.Solids,ppm	3,497	2,900	4,418	3,482	3,627
13.	Sus. Solids,lb	5,091	3,462	5,014	4,305	4,408
14.	Ether Sol.,ppm	3,361	3,360	5,699	3,205	4,146
15.	Ether Sol,lb	4,909	3,968	6,369	3,922	4,941
16.	BOD, ppm	4,167	3,660	3,518	3,467	3,654
17.	BOD, lb	5,729	4,334	3,978	4,313	442
	Skimmer Effluent					
21.	pH	6.4	7.1	6.3	6.2	6.6
22.	Sus.Solids,ppm	1,403	2,131	3,217	1,908	2,356
23.	Sus.Solids,lb	1,947	2,443	3,588	2,403	2,757
-	Sus.Solids, % removed	61.8	29.4	28.4	44.2	37.4
25.	Ether Sol.,ppm	1,371	2,062	3,881	1,525	2,490
26.	Ether Sol.,lb	1,981	2,389	4,200	1,915	2,877
-	Ether Solids, % removed	59.6	39.8	33.7	51.2	41.8
28.	BOD, ppm	2,209	2,698	2,635	2,463	2,558
29.	BOD, lb	3,188	3,260	2,987	3,150	3,134
-	BOD,% removed	44.3	24.8	24.9	27.0	29.1
	Air Flotation Effluent					
2.	Alum,gal.	368	343	285	310	320
3.	Polymer,gal.	259	206	196	225	214
6.	Alum, ppm	457	477	441	417	450
7.	Polymer,ppm	3	2	2	3	2
31.	pH	4.7	5.1	5.3	5.2	5.1
32.	Sus.Solids,ppm	375	529	468	514	481
33.	Sus.Solids,lb	523	639	545	625	586
-	Sus.Solids, % removed	73.1	73.8	84.8	75.0	78.7
35.	Ether Sol.,ppm	317	361	419	438	389
36.	Ether Sol, lb	400	425	492	542	466
-	Ether Sol, % removed	79.8	82.2	88.3	71.7	83.8
38.	BOD, ppm	673	770	895	935	829
39.	BOD, lb	866	902	1,035	1,117	982
-	BOD, % removed	72.8	72.3	65.3	64.5	68.7
41.	Turbidity	248	315	388	386	343
42.	Dissolved Oxygen	6	6	7	9	7
43.	Temperature	107	110	112	110	110

Averages, All Data, By Shifts

The average data for each shift are presented in Table 15. The first shift is midnight to 8 a.m., the second is 8 a.m. to 4 p.m., and the third is 4 p.m. to midnight.

Results were not greatly different for all shifts. Overall removals of contaminants were 84.0 to 89.4% for suspended solids, 87.2 to 92.4% for ether solubles, and 74.9 to 81.6% for BOD. However, removal efficiencies for the Air Flotation cell were generally 2.5 times as high as for the Skimmer unit, i.e. 70 to 88% compared to 20 to 40%. Overall BOD removals were typically 10% lower than for suspended solids and ether solubles. This is explained in part because 50 to 150 ppm soluble BOD are contained in the raw waste which the system does not remove.

Air Flotation effluent contained an overall average of 479 ppm suspended solids, 387 ppm ether solubles, and 826 ppm BOD. The system is undersized and too many high peak load periods occur to obtain a 400 ppm effluent for all contaminants consistently.

Averages, All Data, For Each Polymer Tested

Average data for each polymer tested are given in Table 16. The averages for the Air Flotation unit are not greatly different and, based on the regression analysis, there was no significant performance difference between polymers when the effects of all the other input variables was considered.

Weekly Cycle of Waste Load

All data for which data existed for all three shifts of each day were grouped by days to investigate for the presence of a weekly cycle. The data below show that the waste load on Saturday and Sunday is much lower than during the week, particularly as to pounds of contaminants. Otherwise, Monday followed by Tuesday showed a significantly higher load compared to the remaining week days.

TABLE 17

WEEKLY CYCLE OF WASTE LOAD

(All data was used for which data existed on all 3 shifts.)

	Number of Data Days	Process Waste, gpm	Ether Sol., lb.
Sunday	1	221	639
Monday	8	302	9569
Tuesday	11	301	5385
Wednesday	12	318	3195
Thursday	13	294	4446
Friday	5	290	3212
Saturday	1	192	474

COMPARATIVE COST FOR POLYMER FLOCCULENTS AND COAGULANTS

The following tables list comparative costs for the four polymers and five coagulants tested, f.o.b. point of shipment. Also given is the cost at a dosage of 1 ppm in 500,000 gallons of treated water. Note that there is relatively little difference in the daily cost of polymer treatment at the dosages indicated. But, alum is much cheaper than most of the other coagulants.

TABLE 18

COMPARATIVE COSTS FOR POLYMERS AS OF 12/15/70

Polymer	Pounds	Cost/ Pound	Cost @ 1 ppm* /500,000 gal.
Swift X-400	0 to 1,999	$1.75	$7.29
	2,000 to 4,999	1.70	7.08
	5,000 up	1.65	6.87
Am. Cyan. P-250	100 to 4,999	1.55	6.46
	5,000 to 20,000	1.40	5.83
Dow NP-20	0 to 499	2.55	10.62
	500 to 999	2.05	8.54
	1,000 to 1,999	1.84	7.66
	2,000 to 5,000	1.65	6.87
	5,000 up	1.55	6.46
Nalco 670	0 to 499	2.06	8.58
	500 to 1,999	1.66	6.91
	2,000 to 4,999	1.31	5.46
	5,000 to 19,999	1.26	5.25
	20,000 up	1.21	5.04

* requires 4.165 pounds of polymer

TABLE 19

COMPARATIVE COSTS FOR COAGULANTS AS OF 12/15/70
TRUCK LOAD QUANTITIES

Coagulant	Cost/ Pound	Cost @ 100 ppm* /500,000 gal.
Alum, powder	$0.0300	$12.50
Zinc Chloride, granula	0.1415	58.94
Ferric Sulphate, powder	0.0455	18.95
Sodium Aluminate, pulverized	0.1270	52.90
Ferric Chloride, powder	0.0650	27.07

* 416.5 pounds are required.

SECTION VII

INFLUENCE OF CATHODIC PROTECTION DEVICES

Cathodic protection was installed in the Skimmer and Air Flotation units. The latter included protection of the pressure retention tank, the main body of the Air Flotation cell and also its effluent collecting ring.

TECHNICAL CONSIDERATIONS

Cathodic protection involves constructing an electric cell which is designed to arrest corrosion. For a tank to corrode, iron in the free state (zero valence) must give up two electrons and pass to the ferrous state. The driving force for this reaction has been measured at 0.865 volt. The ferrous iron so produced is capable of losing an additional electron and passing to the ferric state. The driving force for this reaction is 0.45 volt. Equations representing these reactions are:

$Fe \qquad Fe^{++}$ + 2 electrons (Eq. 2)
$Fe^{++} \qquad Fe^{+++}$ + 1 electron (Eq. 3)

To cathodically protect a tank from corroding, one simply impresses a voltage against the tank such that electrons do not leave the iron and, therefore, oxidation of the metal does not occur. Proper voltage at the tank wall must be slightly above 0.865 volt. The Skim tank and the Flotation Cell at Bradley were so protected. This was accomplished by means of a rectifier-anode system.

Figure 26 is a simplified diagram of a basic impressed current cell. Impression of the voltage potentials as outlined above prevent corrosion.

Concerning the role of impressed current in flocculation and waste water clarification, the following are the several mechanisms postulated:

1. Impressed electrical energy acts to enhance the several mechanisms described in Section VI for flocculation. For example, in the anode areas, the pH is lowered because of anion migration and soaps are converted to fatty acids. Thermodynamically speaking, the spontaneous reaction resulting in the formation of a saponified fat is reversed by impressed current.

2. Contaminant particles are repelled from both the anode and cathode after the charges on such particles are altered by impressed current potentials.

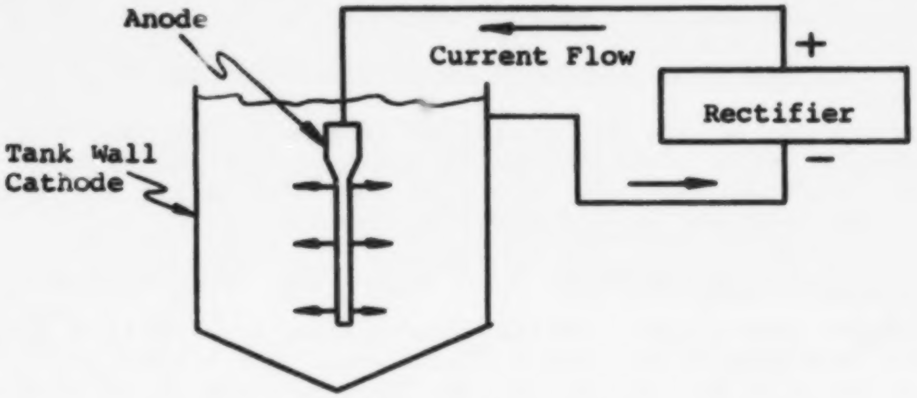

FIGURE 26: BASIC IMPRESSED CURRENT CELL

3. Gas bubbles are formed at both anode and cathode which become attached to contaminent particles and rise to the surface.

The kinetics of impressed current flocculation and clarification were not studied, but such a study and the use of Nernst's equation would probably be of value.

EQUIPMENT DESCRIPTION

Skimmer

Twelve stabilized high silica "Duriron" electrodes functioned as anodes. Duriron anodes have an attritional rate of 2 mg per ampere year. Anodes used in this system were 1-1/2 inch diameter by 5 feet long. This size was used to withstand greater mechanical shock. Only Duriron anodes and steel vessels were employed.

Anode configuration was previously known to have an important bearing on system performance. The arrangement chosen for these studies is described in the following paragraphs, but later work has shown that a three-dimensional configuration is beneficial.

One anode was installed parallel to and 12 inches from the 6 inch inlet distribution pipe. Both pipe and anode are parallel to and 18 inches above the Skimmer floor. Five pairs of anodes were installed parallel to and 17 inches from the side walls. These anodes were installed on a line starting 20 inches above floor level 30 inches from the inlet end to 12 inches below liquid level at the sludge removal structure (grease baffle, inclined deck, and grease take-away conveyor). The sludge removal structure is 12 inches from the effluent release weir. The twelfth anode was installed 12 inches from and parallel to the bottom of the sludge removal structure. Effluent water passed under this structure and was released over a wier at the 5-foot liquid level.

The Skimmer walls were originally covered with a firm thick cake consisting of corrosion products, fat and scale. Severe corrosion existed on tank walls under this coating.

All anodes were installed in parallel circuit. Anode leads were of #8-7 strand cable. The Skimmer, which was grounded at two terminal points, functions as the cathode as this is the structure receiving protection against corrosion. Two terminals of 2 inch by 3 inch copper plate, 1/4 inch thick, with terminal fittings, were used to insure constant and adequate grounding. All anodes in the Skimmer were energized by power from a rectifier. This rectifier was an air cooled, bridge circuit, full wave selenium stack model with choke. Current input was single phase, 115 volt, AC. Output rating was 28 amperes at 18 volts.

Air Flotation System

Seven Duriron anodes were installed in Flotation Cell which is 13 feet, 6 inches diameter, with liquid level to 10 feet 4 inches deep. These were also 1-1/2 inch diameter, 5 feet long. These were installed in perpendicular position 30 inches from the cell wall and of equal distance from each other. The bottom end was 20 inches from the tank floor which was conical.

Pressure Retention Tank

One 1-1/2 inch diameter by 5 foot anode was installed in the retention tank. This unit is 40 inches in diameter by 6 feet 6 inch side walls with dome shaped bottom and top. A potted anode assembly was made with a 2-1/2 inch by 6 inch nipple. Irradiated polyolefin and suitable epoxy produced desired electrical insulation and proper pressure resistant requirements. The assembly was inserted through a 3 inch coupling. A double thread bushing completed the assembly. This anode was in perpendicular position 12 inches from the outside wall.

An anode string was used in the collecting ring. Seven 1-1/8 inch diameter by 9 inch long "Duriron" shell anodes were installed in parallel circuit. Each anode was 5 feet from each other. These were installed 2 inches below water level.

All anodes in the flotation cell, retention tank, and collecting ring were installed in parallel circuit. One rectifier provided DC power for all anodes in all three units of the Air Flotation system.

An air cooled bridge circuit selenimum stack rectifier with single phase, 115 volt input was used. DC current rating was at 22 amperes at 18 volts.

Potentials were measured with multi combination meters designed for corrosion control. A copper-copper sulfate half cell was used with electrode extensions to determine potential profile from anode to cathode. It was used principally to determine if uniform current distribution existed. It was also used at times to determine if a particular anode was effective.

Mechanical failures of operating equipment (particularly skim bars) were the only cause of failure of an anode. A protective shield was installed to prevent damage to anodes when heavy objects fell on the anode system.

IMPRESSED CURRENT TEST PROCEDURES AND RESULTS

The cathodic protection system was operated during the entire period when data was collected for evaluation of flocculants, as well as several months previous. Typical operating conditions were: 6 volts rectifier output, or anode potential, resulting in copper-copper sulfate half-cell readings of 1.2 volts; and 12 to 25 amperes current flow through each of the separate circuits for the Skimmer and Air Flotation units.

Many days of pulsed tests, that is, alternately running with and without current for two hour cycles with sampling of input and output streams every 15 minutes, were conducted. However, the "noise" of the other process variables prevented clear-cut results as to a beneficial effect on flocculation. It has been determined recently that at least three to five days are required for adequate polarization of the vessel. Also, more anodes located in a three-dimensional pattern is beneficial. However, long term cycles and altered anode arrangements were not possible within the time and project funding available. Further, to isolate flocculation effects of impressed current, side by side tests are needed, e.g. two Skimmer units, one with and the other without impressed current, on an identical supply stream. This was not possible at Bradley.

Corrosion was brought under control in all areas where cathodic protection was installed. This is particularly significant since sulfuric acid was introduced in waste water at the Skimmer inlet, and coagulating aids were injected into the waste water stream to the Air Flotation cell and they would normally accelerate corrosion. But the impressed current inhibited corrosion in the retention tank, flotation cell and effluent collecting ring.

Metal surfaces below the water line remained free of adhering deposits of fat and scale forming products. A thick, firm cake did not form.

Our recommendation for future research is that parallel test units are required to provide evaluation of flocculation effects produced with or without impressed current.

IMPRESSED CURRENT RESULTS AT OTHER PLANTS

Recent extensive test results for a full-scale catch basin at a major Swift beef slaughtering plant are summarized in Figure 26. Curves are shown for operation with no treatment, with impressed current only, and with both impressed current and chemicals for removals of grease (Fats, Oils, and Grease [FOG], by standard hexane extraction), COD, and suspended solids.

Fat recovery in the catch basin is particularly intriguing. The addition of impressed current, on the average, increases the efficiency of the catch basin for removing fat. The addition of both chemicals and current, of course, is more spectacular. The influent fat level to the catch basin during the test period varied from an indicated low of 262 ppm to a high of 5158 ppm. The efficiency of the catch basin on fat removal increases as the total fat load increases, particularly if impressed current is applied. For example, on one test day the influent to the catch basin was 5158 ppm of fat. This was reduced to an effluent fat content of 1551 ppm with the aid of impressed current. The addition of chemicals to the catch basin provides further reduction in fat content. With the aid of 200 ppm of ferric sulfate and 2 ppm of anionic polymer, an influent containing 3723 ppm of fat was reduced to 80 ppm in the effluent.

Because of the nature of the effluent at this plant, the COD loading varies from 2600 to over 11,000 ppm. The influence of impressed current is minimal on the COD loading while it does assist in fat removal and this, of course, represents a portion of the COD value. The anolyte stream is an energy source and this serves primarily to prepare the solids for

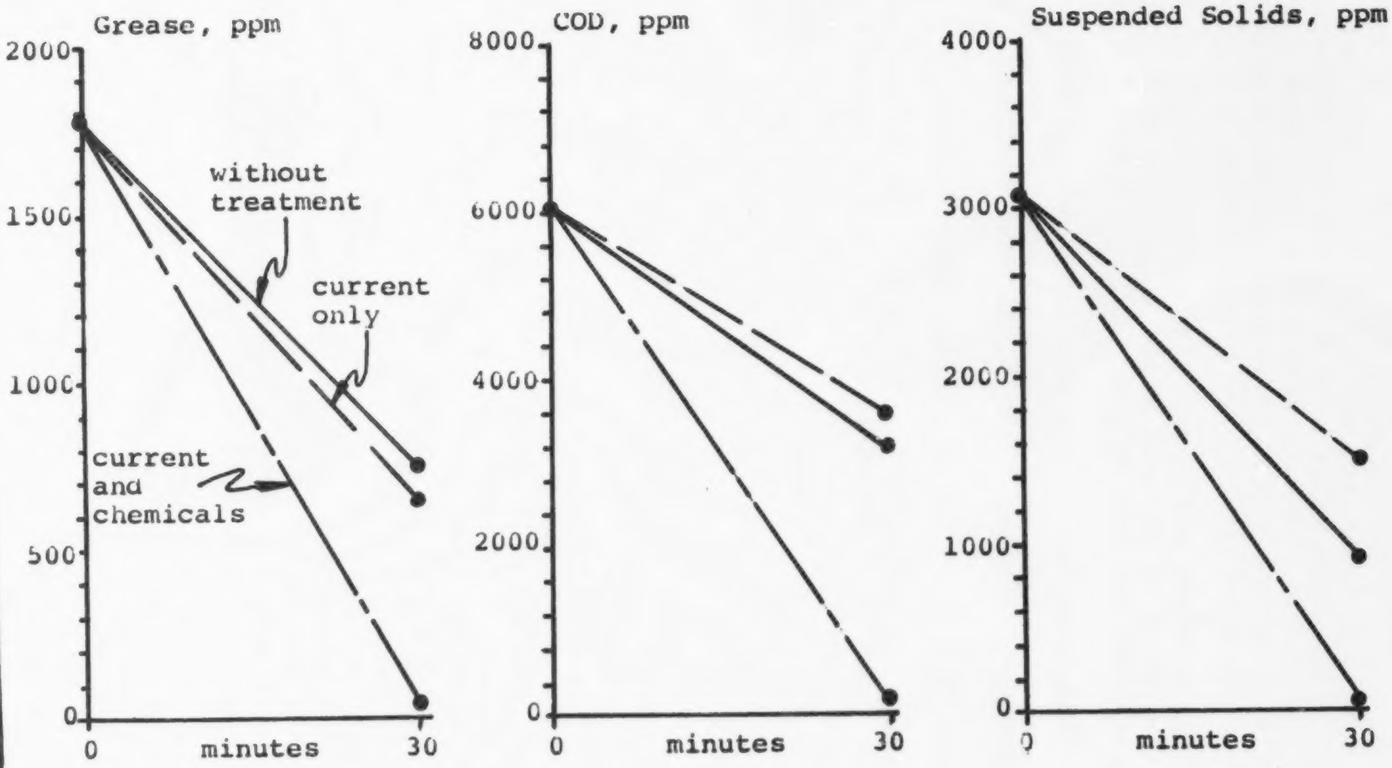

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FIGURE 27: COMPARATIVE SKIM TANK PERFORMANCE AT A SWIFT BEEF SLAUGHTERING PLANT WITH NO TREATMENT, WITH IMPRESSED CURRENT ONLY, AND WITH IMPRESSED CURRENT AND CHEMICALS

chemical treatment. The addition of chemicals to the catch basin reduces the total COD of the effluent to less than 100 ppm.

Suspended solids are difficult to evaluate. The plant effluent varied in measurable suspended solids from 240 ppm to over 7000 ppm. The catch basin, by itself, removes almost 2/3 of this type of material. The addition of impressed current appears to decrease the efficiency of the catch basin for removing suspended solids although actually it is preparing the solids for further treatment because of the effect of the anolyte stream. That is, particles tend to become fragmented and are then susceptible to chemical coagulation. Addition of both chemicals and current reduces the suspended solids to a very low figure, actually measured at 1 ppm, and produced an effluent with a turbidity of 63 Jackson Units.

Test results at a major competitive pork plant indicate that chemical and electrical effects may be synergistic. Specifically, with proper chemical treatment only, reductions of 38% BOD, 44% grease, and 24% suspended solids were experienced. Addition of impressed current increased the removals to 81% BOD, 96% grease, and 91% suspended solids. Use of current only without chemicals effected a 27% BOD reduction but analytically indicated an apparent increase in grease and solids. The analytical indications are caused by anodic de-emulsification which makes the fat and solids more susceptible to solvent extraction and, also, to chemical attack. Physically, fat was removed from the system at the same time analytical procedures indicated an increase.

SECTION VIII

OIL RECOVERY SYSTEM EVALUATION

GENERAL

The lower half of Figure 1 illustrates the overall process flow diagram for the Oil Recovery System. Section IV, entitled "Equipment Addition and Modification", gives details not covered in the subsequent discussion. Analytical procedures are described in the Appendix A, Section XII.

TEST PROCEDURE

Typically, grease skimmings from both the Air Flotation cell and the Skimmer were collected for a 24-hour period in one or the other of the two large treatment tanks. With the exception of two tests (Runs 6 and 15 of Tables 25 through 27), the waste grease collected represented operations when only one polymer was used. The grease skimmings were always dewatered prior to pumping the waste grease to the treatment tanks. The waste grease was always kept warm with the agitators running.

When a tank was to be treated and processed the pH was adjusted to 10, minimum, using 50% sodium hydroxide and allowed to mix for a period of approximately a half hour. Samples were taken intermittently and checked with a pH meter and appropriate adjustments were made. Then the pH was adjusted to approximately 2.5 by the addition of concentrated 66° Baume sulfuric acid. Again, it was mixed for a period of up to a half hour with periodic pH checks. This was the procedure used for all but runs 27 through 34. In these runs, only concentrated sulfuric acid was used to lower the pH to 2.5. It was clearly noticed that, if the pH were not low enough, the oil phase from the DeLaval centrifuge tended to foam quite badly, causing air binding of the recovered oil transport pump.

After startup of the centrifuge and check-out of all the operating instruments and accessories, feed was started through the machine. At least one to two hours was allowed to pass before specific test data were taken. For each run, all operating data were recorded and actual weights and analyses for two cycles were obtained for the oil phase, water phase, and any two of the total sludge, cyclone underflow, and centrifuge sludge streams. The feed rate was not measured but samples were analyzed.

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INITIAL TEST RUNS

A number of shakedown runs were undertaken during which it soon became apparent that operations with a 122 millimeter ring dam would not provide good separation under any conditions. Additionally, it was found that the machine must be operated with a rather dilute sludge discharge so as to prevent caking and build-up of solids within the bowl and serious erosion of the bowl periphery.

During the same operations, it became clear that the presence of filter aids and asbestos fibers used in the plant operations tended to plug up the vertical distribution holes in the DeLaval centrifuge disc stack.

As a result, a 15 foot screw conveyor originally provided was removed and replaced with a 5 gallon pot and Worthington centrifugal pump with interconnecting piping to carry the now liquid sludge outdoors to the sludge bin.

Also, one each of Dorr-Oliver P-50 and P-25 ceramic cyclones and a Bauer 600-3 three inch Nylon cyclone were installed to test them for removal of at least part of the fibers and gritty materials from the waste grease feed.

These same initial test runs showed that it was necessary to operate with an on-feed cycle time of 90 seconds or less, again to prevent build-up of solids within the bowl.

All subsequent tests are discussed below.

TESTS WITH 119, 116 and 114 MILLIMETER RING DAMS

The basic operating and analytical data are given in Tables 25 through 27 and include both the observed and calculated data and analyses. Where certain stream analyses were calculated, these are shown with an asterisk. For example, only two of the three streams, centrifuge sludge, cyclone sludge, or total sludge, were collected, weighed, and analyzed. The third was calculated.

All data were subjected to statistical and graphical analysis and evaluation to determine the effects of feed rate, composition, pH, and temperature on oil recovery percentage and oil phase quality. First, however, feed analyses were calculated from the rates and analyses of the effluent phases and were compared to the actual feed analyses measured. In most cases, they agreed very well. The correlations were run with both calculated and actual feed analyses, eliminating those runs which did not balance well.

The results of these evaluations were as follows:

1. Neither oil quality nor oil recovery were affected significantly within the typical ranges of the data for feed rate composition and pH and temperature. In other words, the original laboratory-determined conditions proved out well.
2. Equivalent results were achieved without using sodium hydroxide in the chemical treatment but rather using sulfuric acid alone.
3. Best performance was achieved when using the 114 millimeter ring dam although results with the 116 millimeter ring dam were nearly as good. Furthermore, no smaller ring dam is indicated.
4. A 45 second "on feed" cycle time was optimum.
5. Typical operating data using the 114 mm ring dam and recommended operating conditions are given in the following paragraphs.

TYPICAL OIL RECOVERY SYSTEM DATA WITH A 114 MM RING DAM

Table 20 gives typical operating and analytical data for the oil recovery system when using the 114 millimeter ring dam for a 45 second "on feed" cycle plus 15 seconds "shoot" time for a total of 1 minute per cycle.

As the table shows, 88.9% of the oil as ether solubles was recovered in the oil phase. Only 1.9% of the original ash content in the feed went to the oil phase. The water phase typically contained 1.8% of the original ether solubles and 43.1% of the original ash. The total sludge contained 3.4% of the original ether solubles and 50.8% of the original ash. It is seen that 37.6% of that ash removed in the total sludge was removed by the cyclone. Observations of a series of laboratory centrifuge spin tube samples of the cyclone sludge compared to the centrifuge sludge indicated that at least 70 to 80% of the coarser particles were removed in the cyclone underflow.

Although the pH of the feed varied from 2.0 to 3.5, it is believed that the pH of 2.5 is the optimum. On several occasions it was found that, when this pH was exceeded, the oil phase tended to foam. This was corrected when somewhat more acid was added to the feed, bringing the pH closer to the 2.5 level. Also, a number of centrifuge spin tests, both in the field and in the laboratory, showed that the pH

TABLE 20

TYPICAL OIL RECOVERY SYSTEM DATA

Basis: 45 seconds "on feed"
1 minute total cycle
114 mm ring dam

	Feed	Oil	Water	Cyclone Sludge	DeLaval Sludge	Total Sludge
Rate, lb./min.	114	29	44	15	26	41
Temp., °F.	180					
Analyses						
Moisture, %	67.0	0.8	95.0	90.6	93.1	92.1
Ether Sol., %	28.3	98.9	1.3	4.4	2.3	2.7
Ether Insol., %	4.7	0.3	3.7	5.0	5.1	5.2
Ash, %	1.7	0.13	1.9	2.4	2.3	2.4
pH	2.6					
Distribution						
Ether Sol. to, %		88.9	1.8	2.0	1.8	3.4
Ash to, %		1.9	43.1	18.6	30.9	50.8

of 2.5 was optimum to yield the clearest water phase. In general, no lower a pH than 2.5 should be used in order to minimize corrosion of the centrifuge and other equipment.

It is believed that somewhat superior separation results would be achieved at higher tmperatures than the 170° to 180° used. However, adequate results were achieved and no higher temperatures than this are suggested in order to minimize corrosion attack.

Based upon all the studies, Table 21 is presented, giving the recommended operating conditions for the oil recovery system.

TABLE 21

RECOMMENDED OPERATING CONDITIONS
FOR OIL RECOVERY SYSTEM

Feed	
Rate, lb/min	114
Temp, °F	180
pH	2.5
Pressure to P-50 Cyclone, psi	40

Centrifuge	
Ring Dam, mm	114
"On Feed" Time, sec	45
Operating Water:	
Supply, psi	45
To Machine, psi	27
Temp, °F	160
Sludge, lb/cycle	26
Water Phase Back Pressure Valve:	
Air to Diaphram, psi	10
Water Pressure, psi	25

CHEMICAL TREATMENT OF FEED TO DELAVAL CENTRIFUGE

Table 25 lists the total amount of raw feed treated and the corresponding amounts of 50% caustic and 66° Baume sulfuric acid used. Concerning the total gallons listed, actually the treatment tanks were emptied only down to the 30 inch level, equivalent to about 1,500 gallons. Thus, when both sodium hydroxide and sulfuric acid were used in the treatment procedure, then a proportionally larger amount was required to treat the residual 1,500 gallons of raw feed from the preceding day's operations. This was not true when only concentrated acid was used.

For 17 days centrifuge runs when both caustic and concentrated sulfuric acid were used, a net total of 58,269 gallons of raw feed were treated and required an average of 143 pounds of 50% sodium hydroxide and 152 pounds of 66° Baume sulfuric acid per 1,000 gallons of feed treated. When only sulfuric acid was used, less than half that above was needed.

OIL YIELD

As indicated in Table 20, for the 114 millimeter data a typical oil recovery (ether solubles) of 88.9% was achieved. Actually, over 95% of the ether solubles would be recovered since only one half the sludge is lost after dewatering. This water, plus the water phase from the centrifuge, is recycled to the process. The raw feed treated and processed averaged 3,430 gallons per day. At the typical 28% ether solubles content, it contained about 7,800 pounds of oil per day. Using a conservative recovery of 90%, the amount of oil recovered averaged 7,000 pounds per day. This represents about 0.75% of total production through the plant.

OIL QUALITY AND MARKET VALUE

Table 20 gives the typical moisture, ether solubles, ether insolubles, and ash content of the recovered oil phase when using optimum conditions. A series of eight oil samples were additionally analyzed for free fatty acid, FAC color, and titer. The results of these analyses are given in Table 22 along with the average values. The sample for 8/7 was considered typical and the further analyses of saponification number, unsaponifiables, and iodine value were also run on it.

TABLE 22

ADDITIONAL QUALITY ANALYSES FOR THE DELAVAL RECOVERED OIL

Run Date	Run No.	FFA %	FAC Color	Titer	Sap. No.	Unsap. %	Iodine Value
8/3/70	10	24.4	21	37.6			
8/5/70	11	20.4	21	36.8			
8/6/70	12	14.8	21	31.5			
8/7/70	13	24.4	21	35.4	198.2	2.5	65.2
8/11/70	14	16.5	21	39.2			
8/12/70	15	23.6	21	34.1			
8/13/70	16	20.3	21	32.0			
8/18/70	17	31.0	27	32.9			
Average		21.9	21	34.9			

A "National Provisioner" quotation for inedible house grease, 37.5 titer, 20 FFA Max, and 39 FAC Max, unbleached, f.o.b. Chicago, carlot basis was 6-5/8 cents per pound, with yellow grease at 6-1/4 cents per pound, as of November 24, 1970. Possible uses for the recovered oil appear to be in the animal feed area and the soap area. If used in animal feeds, the requirement for "feed grade" is that the specific type of product will have been adequately tested to prove its safety for feeding purposes. Currently, a number 2 grade tallow, inedible, in the price range of 6-1/2 cents to 10 cents per pound is being used in animal feeds. At the soap usage level, the indicated value today is in the range of 4-1/2 cents to 6-1/2 cents per pound. To be conservative, a 4-1/4 to 4-5/8 cents per pound value was used in the calculations below.

Based on a recovery of 7,000 pounds of oil per day for 250 operating days (excluding weekend operations), a total 1,750,000 pounds annually would be recovered, having a value of $74,375 to $80,937.

SECTION IX

ECONOMIC EVALUATION

Direct operating costs for the Bradley Waste Water Clarification and Oil Recovery Systems for Monday through Friday operation were calculated and are shown in Table 23. Costs for the Waste Water Clarification System are shown separately from those for the Oil Recovery System. Annual depreciation charges were not included, first of all because no accurate figure is known for the total capital for what were the existing waste treatment facilities; and secondly, because it is felt they would represent a small percentage of the expected total daily overall costs.

Total new capital expenditure under the Grant for both the Waste Water Clarification and Oil Recovery Systems was $150,000. Of this amount, 38%, or $57,000, was expended for additions to the Waste Water Clarification System and 62%, or $93,000, was expended for the Oil Recovery System. The overall total purchase cost of the major equipment amounted to 57% of the total capital investment. Assuming a 10 year life and 365 days of operation, the daily depreciation cost for the additions to the Waste Water Clarification System amount to $15.60. Similarly, the daily depreciation cost for the Oil Recovery System is $25.50.

The total Waste Treatment System is operated 7 days a week. It should be remembered, however, that on the weekends the waste load from the plant is substantially lower than during the normal week and, therefore, chemicals cost and the amount of oil recovered would be reduced. However, it is believed that the direct operating costs shown in Table 23 give a good representation of the situation.

Referring to Table 23, the total daily direct operating cost for the Waste Water Clarification System is $328, of which 38.4% is for chemicals, 4.9% is for utilities, 46% is for direct labor, and 10.7% is for maintenance. A total daily waste flow of 500,000 gallons was assumed.

Total direct operating cost for the Oil Recovery System is $171, of which 4.7% is for chemicals (sulfuric acid), 29.3% for disposal of the combined centrifuge and grit cyclone sludge (after removing approximately 50% of its volume by decanting), 9.9% for utilities, 44.4% for direct labor, and 11.7% for maintenance. As discussed earlier, 7,000 pounds of reclaimed oil obtained each day with a value at 4-1/4 to 4-5/8 cents per pound would yield $298 to $320 per day. This value would generate a "profit" of $127 to $159 per day

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TABLE 23

ESTIMATED DIRECT OPERATING COSTS FOR BRADLEY WASTE TREATMENT SYSTEM

Basis: 500,000 GPD Waste Flow, Monday through Friday

	$/day	$/day	%
WASTE WATER CLARIFICATION			
Chemicals:			
Alum, 500 ppm, 2080 ppd, $0.03/lb.	62		
Swift X-400 polymer, 2 ppm, 8 ppd, $1.65/lb.	13		
Sulfuric acid, 66° Be, drums, 1700 ppd, $0.03/lb.	51		
Total Chemicals		126	38.4
Utilities:			
Power, 1370 Kw hr., $0.0094/Kw hr.	13		
Steam, 3000 ppd, $1.00/1000 lb.	3		
Total Utilities		16	4.9
Direct Labor:			
1 man/shift, $6.29/hr. (incl. fringes but not supervision or materials handling)		151	46.0
Maintenance (excl. depreciation):		35	10.7
TOTAL - WASTE WATER CLARIFICATION		328	100.0
OIL RECOVERY			
Chemicals:			
Sulfuric Acid, 66° Be, drums 260 ppd, $0.03/lb.		8	4.7
Sludge Disposal:			
$150/2100 gal. load every 3 days		50	29.3
Utilities:			
Steam, 3000 ppd, $1.00/1000 lbs.	3		
Power, 1440 Kw hr., $0.0094/Kw hr.	14		
Total Utilities		17	9.9
Direct Labor:			
1.5 men/day, at above rate		76	44.4
Maintenance (excl. depreciation):		20	11.7
TOTAL - OIL RECOVERY		171	100.0

over the direct operating cost of $171 per day for the Oil Recovery System (excluding depreciation). On an overall basis, the value of the oil would offset between 60 to 64% of the grand total daily waste treatment operating cost of $499, excluding depreciation.

At the present time, inedible oil and tallow prices are about 25% above the average for the past 10 years. However, it is also felt that the recovered oil may find a market where its value would approach 6 to 6-1/2 cents per pound at present day prices. In any case, it is believed a fair assumption that over the years, the value of the recovered oil can be expected to offset approximately 60% of the direct operating cost of such a waste treatment facility.

It will be noted that the cost of alum and sulfuric acid represents a high percentage of the overall daily operating cost. The price of 3¢ per pound for alum was based on obtaining it in 100 pound bags in quantity. The price of sulfuric acid is based on obtaining it in 55 gallon drums at a cost of 3¢ per pound. Both costs can be reduced, particularly that of sulfuric acid, if tank truck quantities of alum in solution and of sulfuric acid are utilized.

SECTION X

PUBLICATIONS

1. McFarland, J. R. Water Pollution Abatement for Edible Oil Refineries. Swift & Company. (Presented at American Oil Chemists' Society. New York. October 22, 1968.) 10 p. (Not published.)

2. Clemens, O. A., and J. V. Ziemba. Better Way to Treat Liquid Wastes. Food Engineering. 43(8):47-49, August 1971.

3. Seng, W. C. Removal and Recovery of Fatty Materials from Edible Fat and Oil Refinery Effluents. Swift & Company. (Presented at Second National Symposium on Food Processing Wastes. Denver. March 23-26, 1971.) Proceedings, Second National Symposium on Food Processing Wastes. Environmental Protection Agency, Pacific Northwest Regional Laboratory, Corvallis, Oregon. Water Pollution Control Research Series 12060---03/71. p. 337-366.

4. Ramirez, E. R. Purification of Industrial Waste Water by Electro Coagulation. Swift & Company. (Presented at Wastewater Equipment Manufacturers Association. Chicago. March 16, 1973.) 21 p.

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SECTION XI

GLOSSARY

Air Flotation Unit - The 13 foot 6 inch diameter by 10 foot high cell (Figures 2 and 8) for flotation and removal of waste water contaminants through use of air bubbles and flocculant chemicals.

Coagulant - Alum, ferric sulfate, and other such chemicals.

Coagulant Aid - A synthetic acrylamide polymer.

FAC Color - Method Cc-13a-43, Fat Analysis Committee of the American Oil Chemists Society, for color measurement of oil samples.

Flocculant - Both, for example, alum and Swift X-400 polymer.

JTU - Jackson Turbidity Unit.

Side Tanks - The 400 and 850 gallon steam coil heated holding tanks adjacent to the Skimmer and Air Flotation units, respectively, for temporary storage of skimmings.

Skimmer - The 10 foot by 40 foot rectangular tank (Figures 2 and 7) for quiescent flotation and removal of waste water contaminants from the plant waste water stream without the use of air.

Skimmings - Solid waste and fatty materials floated to and removed from the surface of the Skimmer and Air Flotation units.

Titer - A measure of the solidification point of the fatty acids, by Method Cc-12-59, American Oil Chemists Society.

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SECTION XII

APPENDICES

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APPENDIX A

ANALYTICAL PROCEDURES

TOTAL RESIDUE ON EVAPORATION

A.P.H.A. Standard Methods for Examination of Water and Wastewater, 12th Ed., 1965, p. 423.

When sample contained a large amount of solids the sample size was reduced.

TOTAL SUSPENDED RESIDUE

A.P.H.A. Standard Methods for Examination of Water and Wastewater, 12th Ed., 1965, page 424.

Samples in which the suspended matter was primarily oil or fat sometimes yielded a suspended residue less than the ethyl ether soluble material because of oil passing through the filter or rendering out on drying.

ETHYL ETHER SOLUBLE - SEWAGE

This is a procedure for determining the fat, oil and fatty materials in waste waters. A copy of the procedure is attached. The sample is acidified to split the fatty acids from any soap that might be present.

BIOCHEMICAL OXYGEN DEMAND

A.P.H.A. Standard Methods for Examination of Water and Wastewater, 12th Ed., 1965, pgs. 406-409 and 415-421.

CHEMICAL OXYGEN DEMAND

A.P.H.A. Standard Methods for Examination of Water and Wastewater, 12th Ed., 1965, pags. 510-514.

OXYGEN DEMAND INDEX (Using O.D.I. Reagents)

Manual of Laboratory Methods for Sewage Plants.
Illinois Department of Public Health
Division of Laboratories
January 1970

When the O.D.I. exceeded 420 appropriate dilutions were made to bring the transmission of the sample within the range for the calibration graph.

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CHLORIDES - WATER AND WASTEWATER (Levels of 0.01 to 0.1%)

A copy of the method employed is attached.

OIL IN WASTEWATER AT 10 to 500 PPM

A copy of the method employed is attached.

TURBIDITY

The turbidity of samples was measured using the Hach Laboratory Turbidimeter Model 1860A. Appropriate dilutions were made of the sample when measurements exceeded the range of instrument.

pH - MEASUREMENTS

The pH measurements were made with a pH meter, using conventional methods for standardization.

ANALYSIS OF SAMPLES CONTAINING MORE THAN 25% FAT

MOISTURE AND VOLATILE (Hot Plate Method)

American Oil Chemists Society Offical Method Ca-2b-38.

FAT AND OIL CONTENT (Ethyl Ether Soluble)

The residue from the hot plate moisture is extracted with ethyl ether as directed in the method for ethyl ether soluble. Attached Method No. 1089, beginning with C,3.

INSOLUBLE MATERIAL

The insoluble material = 100%-(% Moisture + % Ethyl Ether Soluble).

RESEARCH METHODS

Swift & Co., R&D Center Method 1101

OIL IN WASTE WATERS AT 10 to 500 PPM

PRINCIPLE: One thousand ml. of sample is extracted with petroleum ether, the petroleum ether is evaporated, the residue is weighed and reported as oil.

A. APPARATUS:

1. Graduated cylinder, 100 and 1000 ml. capacity.
2. Separatory funnels, 2 liter capacity.
3. Beakers, 250 and 800 ml.
4. Gooch crucibles, Coors No. 5, 130 ml. capacity and dia. top rim 55 mm.
5. Asbestos, long fiber acid washed for Gooch crucibles.
6. Filter flask, 1000 or 2000 ml. capacity.
7. Crucible holders, Filtervac No. 3 LaPine Scientific Co. Cat. No. 100-96 or equivalent.

B. REAGENTS:

1. Petroleum ether, A.O.C.S. Specification H 2-41.

C. PROCEDURE FOR EXTRACTED OIL:

1. Measure and record volume of sample using a 1000 ml. graduated cylinder.
2. Transfer sample to a 2-L separatory funnel.
3. Rinse the sample bottle with 250 ml. of petroleum ether (P.E.) and pour rinsing into the graduated cylinder used for measuring the sample. Rinse the graduated cylinder and pour the P.E. into the separatory funnel.
4. Stopper the separatory funnel, shake vigorously for about 30 seconds, and allow the two phases to separate.
5. Draw off the aqueous phase into a 1 liter beaker and decant the P.E. into a 800 ml. beaker.

6. Return the aqueous phase to the separatory funnel, add 250 ml. of P.E. and repeat 4 and 5, decanting the P.E. extract into the 800 ml. beaker containing the first extraction.

   Note: Save the aqueous phase if oil in residue after extraction is to be determined.

7. Evaporate the P.E. on the steam bath to about 50 ml. and transfer to a weighed 250 ml. beaker. Rinse the 800 ml. beaker 2 times with approximately 20 ml. P.E. and add the rinsing to the 250 ml. beaker.

8. Evaporate the P.E. on the steam bath, cool the beakers in a dessicator and weigh. Calculate the ppm of residue as oil as directed in section E.

D. PROCEDURE FOR OIL IN RESIDUE AFTER EXTRACTION WITH PETROLEUM EHTER:

1. Filter the aqueous phase, from C, 6 through a Gooch crucible as directed in Method 1087.

2. Transfer the Gooch crucible to a funnel supported in a weighed 250 ml. beaker. Pour 10 ml. of acetone and then 100 ml. of P.E. through the Gooch crucible collecting the P.E. in the beaker.

3. Evaporate the P.E. on the steam bath, cool the beaker in a dessicator and weigh. Calculate the ppm of residue in the beaker as oil as directed in section E.

E. CALCULATIONS:

$$\text{Oil, ppm} = \frac{(A-C) \times 10^6}{B}$$

A = Gm. of residue from C, 8 or D, 3.
B = Ml. of sample from C, 1.
C = Gms of residue in solvent used for extraction. See Section F.

F. DETERMINATION OF RESIDUE IN SOLVENT:

1. Evaporate 500 ml. of P.E. from a weighed 250 ml. beaker on the steam bath by adding 100 ml. evaporate and add another 100 ml.

2. After the final addition of 100 ml. P.E., evaporate, cool the beaker in dessicator, and weigh.
3. Calculate the residue in 500 ml. P.E. and 100 ml. P.E.
4. Repeat F, 1, 2 and 3 using the same beaker.

Rev. June, 1970

CHLORIDE - WATER & WASTE WATER
(LEVELS OF 0.01% TO 0.1%)

PRINCIPLE: Twenty-five ml. of a neutral or slightly alkaline solution is titrated with 0.0705 N $AgNO_3$ using a potassium chromate solution as an indicator.

A. **APPARATUS:**

1. Buret, 50 ml.
2. Erlenmeyer flask, 500 ml.
3. Pipet, 25 ml.

B. **REAGENTS:**

1. Silver nitrate, A.C.S. grade.
2. Sodium chloride, A.C.S. grade.
3. Potassium chromate, A.C.S. grade.
4. Indicator papers to cover pH range from 3 to 10.
5. Sodium hydroxide, A.C.S. grade.
6. Sulfuric acid, sp. gr. 1.84 A.C.S. grade.
7. Ammonium acetate, A.C.S. grade.

C. **SOLUTION:**

1. Silver nitrate, 0.0705N. Dissolve 11.980 g. in distilled water, dilute to 1 liter in a volumetric flask, and mix thoroughly.
2. Sodium chloride, 0.0705N. Dissolve 4.121 g. NaCl (dried at 140°C) in distilled water, dilute to 1 liter in a volumetric flask, and mix thoroughly.
3. Potassium chromate indicator. Dissolve 50 g. of K_2CrO_4 in about 200 ml. distilled water, add silver nitrate solution until a definite red recipitate is formed. Allow to stand overnight, filter and dilute the filtrate to 1 liter.

4. Sodium hydroxide, 5%. Dissolve 5 g. of sodium hydroxide in 100 ml. of distilled water.

5. Nitric acid, 10%. Add 10 ml. of conc HNO_3 to 90 ml. of distilled water or sulfuric acid, 5%, add 5 ml. of conc H_2SO_4 to 95 ml. of distilled water.

6. Ammonium acetate-acetic acid solution. Dissolve 10 g. of ammonium acetate and 1 ml. of acetic acid in 1000 ml. of distilled water.

D. STANDARDIZATION OF SILVER NITRATE SOLUTION:

1. Pipet 25 ml. of sodium chloride into a 500 ml. Erlenmeyer flask, add 75 ml. of ammonium acetate-acetic acid solution C, 6 and 1 ml. of K_2CrO_4 indicator solution.

2. Titrate with 0.0705 N $AgNO_3$ to the end point, the appearance of a definite reddish color. Add the silver nitrate in increments of 0.2 ml. when approaching the end point.

3. Titrate a blank (25 ml. of distilled water plus 75 ml. of ammonium acetate-acetic acid solution C, 6 and 1 ml. of K_2CrO_4 indicator soln.) as directed in D, 2.

$$\text{Normality of } AgNO_3 \text{ soln.} = \frac{\text{Ml. } 0.0705 \text{ N NaCl} \times 0.0705}{A-B}$$

$$= \frac{1.762}{A-B}$$

A = ml. $AgNO_3$ solution used to titrate the salt solution D, 2.

B = ml. $AgNO_3$ solution used to titrate the blank D,3.

E. PROCEDURE:

1. If the sample contains suspended matter filter a portion through Whatman folded 2V filter paper. See Notes G, 1 and 2.

2. Pipet 25 ml. of sample or filtrate into a 500 ml. Erlenmeyer flask. If pH of the sample is outside the range of 4 to 8 adjust pH to within this range using 5% NaOH or 10% HNO_3. pH may be checked with indicator paper before and after any adjustment.

3. Add 75 ml. of ammonium acetate-acetic acid solution C, 6 using a graduated cylinder, 1 ml. of K_2CrO_4 indicator and titrate with 0.0705 N $AgNO_3$ using 0.2 ml. increments when approaching the end point, the appearance of a definite reddish color.

4. Titrate a blank (25 ml. of distilled water and 75 ml. of ammonium acetate-acetic acid solution C, 6) as directed in E, 3.

F. CALCULATIONS:

$$\text{\% chloride, chlorine} = \frac{(S-B) \times N \times 35.46 \times 100}{V \times 1000}$$

$$= \frac{(S-B) \times N \times 3.546}{V} = (S-B) \times 0.01$$

$$\text{ppm chloride} = \text{mg/l} = \frac{(S-B) \times N \times 35{,}460}{V} = (S-B) \times 100$$

S = Ml. of $AgNO_3$ solution used for titration of the sample E, 3.

B = Ml. of $AgNO_3$ solution used for titration of the blank, E, 4.

V = Ml. of sample pipetted for analysis.

When N = 0.0705 ± 0.007 and V = 25 ml. and the titration for the blank does not exeed 0.2 ml., the simplified equation may be used.

% chloride, chlorine = S x 0.01

ppm = S X 100

G. NOTES:

1. If the sample is highly colored, pipet 25 ml. of sample into a 150 ml. in beaker, add 3 ml. $Al(OH)_3$ suspension, mix, allow to settle, filter, wash, and combine filtrate and washing. Transfer to a 500 ml. Erlenmeyer flask, adjust pH, dilute to 100 and proceed as directed beginning with E, 3.

2. If sulfide, sulfite, or thiosulfate is present, make the water alkaline to phenolphthalein with sodium hydroxide solution. Add 1 ml. H_2O_2 and stir. Neutralize with sulfuric acid and then proceed with the analysis beginning with E, 2.

3. Report results below 0.1% to the nearest 0.005%. Report results above 0.1% to the nearest 0.01%.

Swift & Co., R&D Center

Method 1089
Rev. Oct. 1969

ETHYL ETHER SOLUBLE - SEWAGE

PRINCIPLE: The sample is acidified with hydrochloric acid and then evaporated to dryness. The grease is extracted from the residue with ethyl ether.

A. APPARATUS:

1. The apparatus is exactly as described in Ja 8a-49, Oil - Water, A.P.H.A. Method, A, 1 to 9 inclusive.

2. Desiccator containing Desichlora or Drierite, indicating type.

B. REAGENTS:

1. The reagents are exactly as described in Ja 8a-49, Oil - Water, A.P.H.A. Method, B, 1 and 2.

2. Ethyl Ether, U.S.P. Grade. Determine nonvolatile residue by evaporating five 100 ml. portion of the ethyl ether. If the residue exceeds 0.005 g (5 mg) calculate the residue per 125 ml. to the nearest 0.001 g. and use this value for B in the calculations. Check each new lot or drum of ethyl ether for nonvolatile residue.

C. PROCEDURE:

1. Transfer 100 ml. of the well mixed sample to a 250 ml. beaker using a 100 ml. graduate cylinder.

2. Add 0.5 ml. of HCl, sp. gr. 1.19 and mix thoroughly. See Note E, 1. Evaporate to dryness on a steam bath or hot plate, remove and cool to room temperature. See Note E, 2.

3. Add 100 ml. of ethyl ether, warm on the steam bath and stir thoroughly to dissolve the grease and oil in the residue.

4. Filter the soln. thru Whatman No. 2 or equivalent grade filter paper, collecting the filtrate in a tared 250 ml. beaker. Rinse the beaker with 10 to 20 ml. of ethyl ether and transfer to the filter. Wash the paper with two 10 ml. portions of ethyl ether.

5. Place the 250 ml. beaker under a stream of clean, dry air on a steam bath and evaporate off the ethyl ether.

6. Transfer the beaker to an air oven maintained at 103° ± 1°C and dry for 1-1/2 hours. Remove from the oven, place in a desiccator, cool to room temperature and weigh to the nearest 0.001.

D. CALCULATIONS:

$$\text{Ethyl ether soluble, ppm} = \frac{(A-B) \times 1{,}000{,}000}{100}$$

$$= (A-B) \times 10{,}000$$

A = Weight of residue from sample in grams, C, 7.

B = Weight of residue in ethyl ether in grams, B, 2.

E. NOTES:

1. Test solution with indicator paper. If the pH is more than pH 1.0 add another 0.5 ml. of conc. HCl, mix thoroughly and test.

2. Remove immediately when the last traces of moisture evaporate, or only a trace of moisture remains.

APPENDIX B

DETERMINATION OF FLOW RATES

A technique for the determination of flow rates in circumstances where weirs cannot be used was developed for the in-plant survey. Essentially, the method consists of three steps as follows:

1. Samples of effluent are taken and either the chloride content or specific conductance (expressed as sodium chloride) is determined.
2. A concentrated solution of sodium chloride at a known concentration is metered into the sewer downstream from the sample point in step 1.
3. Samples are taken downstream from step 2. The unknown flow rate can then be calculated from the following:

$$R_2 = \frac{R_1\ (c-b)}{b-a}$$

Where, R_1 = flow rate of brine solution added, l/min
R_2 = flow rate of unknown stream, l/min
a = initial (Step 1) chloride concentration in the R_2 stream being measured by chloride titration or conductivity, mg/l
b = chloride concentration downstream (Step 3) after brine injection, Mg/l
c = chloride concentration of the R_1 brine solution added, mg/l

Example:

A 50,000 mg/l sodium chloride brine solution, containing 30,500 mg/l chloride, is added to a sewer stream at a rate of 4 l/min. The initial stream chloride concentration (a) is 100 mg/l, and the downstream chloride concentration (b) is found to be 500 mg/l. Then the unknown (R_2) stream flow is:

$$R_2 = \frac{(4)\ (30,500-500)}{(500-100)} = 300 \text{ l/min.}$$

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APPENDIX C

EVALUATION OF FLOCCULANTS DATA

TABLE 24

WASTE WATER CLARIFICATION EXPERIMENTAL DATA

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
1	2 6/10/7	0	0.	0.	130800.	273.	0.	0.0
2	3 6/10/7	400	0.	152.	147800.	308.	0.	2.0
3	1 6/11/7	400	0.	288.	123600.	258.	0.	4.6
4	2 6/11/7	400	104.	250.	139200.	290.	150.	3.6
5	3 6/11/7	400	224.	224.	94600.	197.	475.	4.7
6	1 6/12	400	224.	224.	118800.	248.	378.	3.7
7	2 6/12	400	390.	270.	123200.	257.	634.	4.3
8	3 6/12	400	290.	262.	112000.	233.	519.	4.6
9	1 6/13/7	400	328.	200.	117000.	244.	562.	3.4
10	2 6/13/7	400	328.	200.	97000.	202.	678.	4.1
11	3 6/13/7	400	314.	150.	62000.	129.	1015.	4.8
12	1 6/14/7	400	224.	144.	115200.	240.	390.	2.5
13	2 6/14/7	400	224.	192.	104800.	218.	428.	3.6
14	3 6/14/7	400	208.	167.	98000.	204.	426.	3.4
15	1 6/15/7	400	328.	184.	113600.	237.	579.	3.2
16	2 6/15/7	400	288.	192.	136400.	284.	423.	2.8
17	3 6/15/7	400	310.	220.	108000.	225.	575.	4.0
18	1 6/16/7	400	320.	224.	140800.	293.	455.	3.1
19	2 6/16/7	400	322.	140.	132800.	277.	486.	2.1
20	3 6/16/7	400	304.	224.	169200.	352.	360.	2.6
21	1 6/17/7	400	304.	224.	203600.	424.	299.	2.2
22	2 6/17/7	400	400.	270.	194200.	405.	412.	2.7
23	3 6/17/7	400	440.	242.	171800.	358.	513.	2.8
24	1 6/18/7	400	400.	200.	201800.	420.	397.	1.9
25	2 6/18/7	400	335.	185.	108200.	225.	620.	3.4
26	3 6/18/7	400	476.	215.	143400.	299.	665.	3.0
27	1 6/19/7	400	440.	200.	119200.	248.	739.	3.2

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TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
28	1 6/24/7	400	326.	198.	137400.	286.	475.	2.8
29	2 6/24/7	250	374.	115.	145000.	302.	517.	1.5
30	3 6/24/7	250	359.	252.	125600.	262.	573.	4.0
31	1 6/25/7	250	367.	268.	148400.	309.	495.	3.6
32	2 6/25/7	250	416.	159.	136800.	285.	609.	2.3
33	3 6/25/7	250	339.	333.	130800.	273.	519.	5.1
34	1 6/26/7	250	348.	212.	144200.	300.	483.	2.9
35	2 6/29/7	250	306.	287.	156400.	326.	392.	3.6
36	1 6/30/7	250	383.	367.	178000.	371.	431.	4.1
37	2 6/30/7	250	356.	189.	187000.	390.	381.	2.0
38	3 6/30/7	250	351.	235.	168800.	352.	417.	2.7
39	1 7/1/70	250	385.	193.	182200.	380.	423.	2.1
40	2 7/1/70	250	343.	240.	161000.	335.	427.	2.9
41	3 7/1/70	250	371.	149.	159200.	332.	467.	1.8
42	1 7/2/70	250	371.	149.	139800.	291.	532.	2.1
43	2 7/2/70	250	341.	255.	134800.	281.	507.	3.7
44	2 7/6/70	920	298.	213.	89600.	187.	667.	4.7
45	3 7/6/70	920	221.	133.	176400.	368.	251.	1.5
46	1 7/7/70	250	304.	133.	104400.	218.	583.	2.5
47	2 7/7/70	250	398.	143.	146000.	304.	546.	1.9
48	3 7/7/70	250	371.	149.	128800.	268.	577.	2.3
49	1 7/8/70	250	332.	149.	139600.	291.	476.	2.1
50	2 7/8/70	250	332.	133.	111600.	233.	595.	2.3
51	3 7/8/70	250	332.	133.	141600.	295.	469.	1.8
52	1 7/9/70	250	332.	133.	158400.	330.	419.	1.6
53	2 7/9/70	250	319.	133.	136000.	283.	470.	1.9
54	3 7/9/70	250	236.	111.	115000.	240.	412.	1.9

TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
55	1 7/10/7	250	221.	131.	133800.	279.	331.	1.9
56	2 7/10/7	250	281.	141.	121200.	253.	465.	2.3
57	3 7/21/7	20	296.	133.	99600.	208.	596.	2.6
58	1 7/22/7	20	324.	234.	127600.	266.	509.	3.6
59	2 7/22/7	20	388.	153.	112000.	233.	694.	2.7
60	3 7/22/7	20	458.	258.	100400.	209.	913.	5.1
61	1 7/23/7	20	472.	346.	133600.	278.	708.	5.1
62	2 7/23/7	20	414.	118.	125600.	262.	660.	1.8
63	3 7/23/7	20	420.	119.	114800.	239.	733.	2.0
64	1 7/24/7	20	420.	119.	110000.	229.	765.	2.1
65	2 7/24/7	20	325.	232.	128000.	267.	508.	3.6
66	2 7/27/7	20	443.	295.	196400.	409.	452.	3.0
67	3 7/27/7	20	327.	265.	162400.	338.	403.	3.2
68	1 7/28/7	20	327.	265.	200000.	417.	327.	2.6
69	3 7/29/7	20	369.	154.	187400.	390.	395.	1.6
70	1 7/30/7	20	678.	305.	237600.	495.	571.	2.5
71	2 7/30/7	20	310.	200.	190000.	396.	327.	2.1
72	1 7/31/7	20	158.	281.	154000.	321.	206.	3.6
73	1 8/3/70	670	240.	111.	139200.	290.	345.	1.6
74	2 8/3/70	670	355.	117.	138800.	289.	512.	1.6
75	3 8/3/70	670	283.	191.	99200.	207.	572.	3.8
76	1 8/4/70	670	414.	237.	134000.	279.	618.	3.5
77	2 8/4/70	670	610.	211.	139800.	291.	874.	3.0
78	3 8/4/70	670	501.	149.	139000.	290.	722.	2.1
79	1 8/5/70	670	205.	136.	152000.	317.	270.	1.8
80	2 8/5/70	670	296.	371.	135600.	283.	438.	5.4
81	3 8/5/70	670	192.	254.	122600.	255.	313.	4.1

TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
82	1 8/6/70	670	88.	339.	147400.	307.	120.	4.6
83	2 8/6/70	670	88.	200.	129600.	270.	137.	3.0
84	3 8/6/70	670	88.	186.	117200.	244.	151.	3.1
85	1 8/7/70	670	376.	150.	148800.	310.	506.	2.0
86	2 8/7/70	670	332.	265.	120000.	250.	553.	4.4
87	3 8/7/70	670	332.	265.	128000.	267.	519.	4.1
88	1 8/10/7	250	351.	281.	141800.	295.	496.	3.9
89	2 8/10/7	250	371.	296.	152000.	317.	489.	3.9
90	3 8/10/7	250	332.	265.	135000.	281.	492.	3.9
91	1 8/11/7	250	558.	254.	175400.	365.	637.	2.9
92	2 8/11/7	400	619.	337.	159600.	333.	776.	4.2
93	3 8/11/7	400	439.	142.	134000.	279.	657.	2.1
94	1 8/12/7	400	255.	341.	168000.	350.	304.	4.0
95	2 8/12/7	400	273.	304.	160000.	333.	342.	3.8
96	3 8/12/7	400	223.	248.	135600.	283.	330.	3.6
97	1 8/13/7	400	160.	149.	162400.	338.	197.	1.8
98	2 8/13/7	400	170.	174.	146400.	305.	232.	2.3
99	1 8/17/7	400	294.	156.	115800.	241.	510.	2.7
100	2 8/17/7	400	354.	221.	146400.	305.	484.	3.0
101	3 8/17/7	400	221.	221.	161200.	336.	275.	2.7
102	1 8/18/7	250	608.	359.	178000.	371.	684.	4.0
103	2 8/18/7	250	455.	322.	146800.	306.	621.	4.3
104	3 8/18/7	250	362.	208.	119600.	249.	607.	3.4
105	1 8/19/7	250	322.	202.	146600.	305.	440.	2.7
106	2 8/19/7	250	376.	269.	143400.	299.	525.	3.7
107	1 8/20/7	250	157.	157.	128400.	268.	245.	2.4
108	2 8/20/7	250	207.	163.	123400.	257.	336.	2.6

TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
109	3 8/20/7	250	133.	184.	146800.	306.	182.	2.5
110	1 8/21/7	250	361.	147.	159200.	332.	454.	1.8
111	2 8/21/7	250	215.	288.	118000.	246.	366.	4.9
112	3 8/21/7	250	296.	118.	88000.	183.	674.	2.7
113	1 8/24/7	400	344.	142.	156600.	326.	440.	1.8
114	2 8/24/7	400	384.	173.	122600.	255.	627.	2.8
115	3 8/24/7	400	296.	119.	103000.	215.	576.	2.3
116	1 8/25/7	400	477.	276.	116400.	243.	821.	4.7
117	2 8/25/7	400	360.	203.	108000.	225.	669.	3.7
118	3 8/25/7	400	318.	177.	94000.	196.	678.	3.7
119	1 8/26/7	400	214.	138.	120000.	250.	357.	2.3
120	2 8/26/7	400	223.	221.	112000.	233.	398.	3.9
121	3 8/26/7	400	186.	157.	96000.	200.	388.	3.2
122	1 8/27/7	400	166.	122.	114000.	238.	292.	2.1
123	2 8/27/7	400	133.	133.	101200.	211.	263.	2.6
124	3 8/27/7	400	118.	118.	81000.	169.	294.	2.9
125	1 8/28/7	400	129.	126.	106000.	221.	244.	2.3
126	1 9/3/70	670	527.	333.	195400.	407.	540.	3.4
127	2 9/3/70	670	232.	292.	190200.	396.	244.	3.0
128	3 9/3/70	670	52.	310.	153600.	320.	68.	4.0
129	1 9/4/70	670	461.	207.	144000.	300.	641.	2.8
130	2 9/4/70	670	428.	194.	144000.	300.	595.	2.7
131	3 9/4/70	670	359.	195.	154000.	321.	467.	2.5
132	1 9/8/70	670	371.	149.	160400.	334.	464.	1.8
133	2 9/8/70	670	340.	143.	140600.	293.	485.	2.0
134	3 9/8/70	670	295.	193.	167000.	348.	353.	2.3
135	1 9/9/70	670	274.	186.	192800.	402.	285.	1.9

TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
136	2 9/9/70	670	245.	169.	121200.	253.	406.	2.8
137	3 9/9/70	670	308.	231.	198000.	413.	311.	2.3
138	1 9/10/7	670	355.	244.	180000.	375.	395.	2.7
139	2 9/10/7	670	288.	207.	156800.	327.	368.	2.6
140	3 9/10/7	670	249.	167.	160200.	334.	312.	2.0
141	1 9/11/7	670	415.	415.	193000.	402.	430.	4.3
142	2 9/11/7	670	355.	355.	168000.	350.	424.	4.2
143	3 9/11/7	670	267.	267.	165400.	345.	323.	3.2
144	1 9/14/7	20	629.	211.	205800.	429.	612.	2.0
145	2 9/14/7	20	322.	190.	212000.	442.	305.	1.7
146	3 9/14/7	20	265.	190.	206000.	429.	258.	1.8
147	1 9/15/7	0	0.	0.	0.	0.	0.	0.0
148	2 9/15/7	0	0.	0.	0.	0.	0.	0.0
149	3 9/15/7	20	422.	359.	199400.	415.	424.	3.6
150	1 9/16/7	20	350.	494.	232600.	485.	301.	4.2
151	2 9/16/7	20	359.	474.	203200.	423.	354.	4.6
152	3 9/16/7	20	248.	326.	181600.	378.	273.	3.6
153	1 9/17/7	20	231.	430.	215200.	448.	215.	4.0
154	2 9/17/7	20	164.	326.	198000.	413.	166.	3.3
155	3 9/17/7	20	268.	352.	186600.	389.	288.	3.7
156	1 9/18/7	20	448.	227.	245600.	512.	365.	1.8
157	2 9/18/7	20	469.	203.	198000.	413.	474.	2.0
158	1 9/21/7	250	529.	303.	191000.	398.	554.	3.1
159	2 9/21/7	250	555.	291.	142600.	297.	779.	4.0
160	3 9/21/7	250	465.	265.	190800.	398.	488.	2.7
161	1 9/22/7	250	508.	224.	235200.	490.	433.	1.9
162	2 9/22/7	250	504.	202.	144000.	300.	702.	2.8

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TABLE 24 (Continued)

1a Run No.	1b Shift and Date	1c Poly Type	2 Alum gal.	3 Poly gal.	4 Raw Waste gal.	5 Raw Waste gpm	6 Alum ppm	7 Poly ppm
163	3 9/22/7	250	371.	149.	141800.	295.	524.	2.1
164	1 9/23/7	250	371.	149.	178000.	371.	418.	1.6
165	2 9/23/7	250	278.	149.	122200.	255.	457.	2.4
166	3 9/23/7	250	265.	133.	164000.	342.	324.	1.6
167	1 9/24/7	250	266.	178.	153200.	319.	348.	2.3
168	2 9/24/7	250	149.	130.	131800.	275.	227.	2.1
169	3 9/24/7	250	160.	160.	95000.	198.	338.	3.3
170	1 9/25/7	250	355.	355.	131400.	274.	542.	5.4
171	2 9/25/7	250	271.	303.	147000.	306.	370.	4.1
172	1 9/28/7	400	384.	118.	118000.	246.	652.	2.0
173	2 9/28/7	400	370.	119.	133400.	278.	555.	1.7
174	3 9/28/7	400	296.	119.	113200.	236.	524.	2.1
175	1 9/29/7	400	296.	145.	187000.	390.	317.	1.5
176	2 9/29/7	400	424.	230.	203200.	423.	418.	2.2
177	3 9/29/7	400	415.	326.	195800.	387.	447.	3.5
178	1 9/30/7	400	285.	196.	206800.	431.	276.	1.9
179	2 9/30/7	400	261.	174.	160000.	333.	326.	2.1
180	3 9/30/7	400	266.	224.	124800.	260.	428.	3.5
181	1 10/1/7	400	240.	192.	123200.	257.	390.	3.1
182	2 10/1/7	400	276.	232.	122200.	255.	453.	3.8
183	3 10/1/7	400	332.	225.	145800.	304.	455.	3.1
184	1 10/2/7	400	229.	199.	136000.	283.	337.	2.9

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TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 Suspended Solids lb	14 Ether Solubles ppm	15 Ether Solubles lb	16 BOD ppm	17 BOD lb
1	11.1	1500.	1636.	740.	807.	2400.	2618.
2	9.9	1020.	1257.	770.	949.	1010.	1244.
3	6.2	1910.	1968.	2540.	2618.	1300.	1340.
4	9.4	560.	650.	530.	615.	1110.	1288.
5	11.4	3720.	2934.	3210.	2532.	5600.	4418.
6	6.1	4550.	4508.	7100.	7034.	1900.	1882.
7	6.1	2150.	2209.	2720.	2794.	2480.	2548.
8	4.5	650.	607.	1010.	943.	1090.	1018.
9	4.1	1180.	1151.	960.	936.	2220.	2166.
10	5.5	540.	436.	380.	307.	560.	453.
11	6.4	380.	196.	350.	180.	580.	299.
12	6.5	1260.	1210.	720.	691.	560.	538.
13	6.3	1340.	1171.	1290.	1127.	980.	856.
14	6.1	130.	106.	120.	98.	300.	245.
15	1.6	17340.	16428.	200.	189.	5000.	4737.
16	6.4	18990.	21602.	94310.	107284.	5000.	5687.
17	11.5	14610.	13159.	21130.	19032.	5000.	4503.
18	6.0	29375.	34494.	32850.	38574.	5000.	5871.
19	6.0	10984.	12165.	12030.	13323.	5040.	5582.
20	6.5	2786.	3931.	4110.	5799.	4720.	6660.
21	9.5	1324.	2248.	1850.	3141.	1880.	3192.
22	11.8	3925.	6357.	4870.	7887.	4160.	6737.
23	8.9	2020.	2894.	2970.	4255.	2960.	4241.
24	9.3	2950.	4964.	4520.	7607.	3440.	5789.
25	5.7	3085.	2783.	3250.	2932.	5440.	4908.
26	6.3	10485.	12539.	19210.	22974.	5000.	5979.
27	8.1	6925.	6884.	8090.	8042.	5000.	4970.

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TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 lb	14 Ether Solubles ppm	15 lb	16 BOD ppm	17 lb
28	7.4	1300.	1489.	3806.	4361.	2360.	2704.
29	10.2	1080.	1306.	2066.	2498.	2040.	2466.
30	6.2	120.	125.	1124.	1177.	3000.	3142.
31	11.2	2580.	3193.	3105.	3842.	5000.	6188.
32	7.6	460.	524.	635.	724.	1670.	1905.
33	7.1	3220.	3512.	3224.	3516.	5000.	5454.
34	6.8	2650.	3186.	2859.	3438.	5000.	6013.
35	10.8	4860.	6339.	4465.	5824.	5000.	6521.
36	11.8	1180.	1751.	725.	1076.	3840.	5700.
37	9.4	670.	1044.	590.	920.	850.	1325.
38	9.2	755.	1062.	610.	858.	930.	1309.
39	11.5	625.	949.	600.	911.	1410.	2142.
40	8.2	525.	704.	455.	610.	1680.	2255.
41	10.9	2170.	2881.	1880.	2496.	1880.	2496.
42	11.7	1200.	1399.	1500.	1748.	840.	979.
43	4.8	2390.	2686.	2150.	2417.	4884.	5490.
44	8.6	880.	657.	620.	463.	2120.	1584.
45	11.8	2680.	3942.	3310.	4869.	4880.	7179.
46	12.2	3550.	3090.	3640.	3169.	4580.	3987.
47	8.9	3300.	4018.	4440.	5406.	2320.	2824.
48	9.5	1180.	1267.	860.	923.	2240.	2406.
49	11.2	970.	1129.	930.	1082.	1580.	1839.
50	11.3	810.	753.	1830.	1703.	3840.	3574.
51	8.7	2210.	2609.	1950.	2302.	2300.	2716.
52	11.5	3440.	4544.	2900.	3831.	3200.	4227.
53	6.0	1430.	1621.	1540.	1746.	2760.	3130.
54	6.7	370.	354.	390.	374.	740.	709.

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TABLE 24 (Continued)

RAW WASTE

1a	11	12	13	14	15	16	17
Run		Suspended Solids		Ether Solubles		BOD	
No.	pH	ppm	lb	ppm	lb	ppm	lb
55	7.0	880.	981.	920.	1026.	1620.	1807.
56	6.9	1590.	1607.	570.	576.	2380.	2405.
57	9.2	5550.	4610.	5650.	4693.	10800.	8971.
58	11.4	930.	989.	1240.	1319.	1900.	2021.
59	11.0	7280.	6800.	4700.	4390.	6520.	6090.
60	11.6	5190.	4345.	5160.	4320.	10240.	8574.
61	11.7	4690.	5225.	4530.	5047.	8320.	9270.
62	10.9	2070.	2168.	3120.	3268.	5400.	5656.
63	8.6	1480.	1416.	1700.	1627.	2200.	2106.
64	11.0	1660.	1522.	1320.	1210.	2420.	2220.
65	11.4	890.	950.	1480.	1579.	1860.	1985.
66	9.0	1060.	1736.	1830.	2997.	1880.	3079.
67	7.1	680.	921.	380.	514.	460.	623.
68	11.1	710.	1184.	340.	567.	1490.	2485.
69	5.9	16410.	25647.	11650.	18207.	5000.	7814.
70	11.3	1620.	3210.	400.	792.	3040.	6024.
71	6.6	1520.	2408.	1500.	2376.	3520.	5577.
72	12.7	5010.	6434.	5710.	7333.	5000.	6421.
73	11.8	1440.	1671.	1160.	1346.	1040.	1207.
74	6.4	6990.	8091.	6857.	7937.	3040.	3519.
75	6.8	2230.	1844.	2452.	2028.	3600.	2978.
76	6.9	5630.	6291.	5370.	6001.	4800.	5364.
77	7.9	7510.	8756.	6775.	7899.	4320.	5036.
78	9.9	5200.	6028.	4681.	5426.	5280.	6120.
79	8.4	3015.	3822.	3041.	3855.	4080.	5172.
80	10.8	2620.	2962.	2420.	2736.	2170.	2454.
81	11.1	2780.	2842.	3667.	3749.	2560.	2617.

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TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 lb	14 Ether Solubles ppm	15 lb	16 BOD ppm	17 lb
82	6.2	450.	553.	1281.	1574.	2160.	2655.
83	11.5	2100.	2269.	2762.	2985.	4800.	5188.
84	7.4	8585.	8391.	9913.	9689.	9600.	9383.
85	6.2	1400.	1737.	1260.	1563.	2320.	2879.
86	6.2	1500.	1501.	1210.	1210.	1480.	1481.
87	10.4	3750.	4003.	4080.	4355.	4400.	4697.
88	11.3	8590.	10158.	7280.	8609.	5040.	5960.
89	11.4	4070.	5159.	4520.	5729.	5280.	6693.
90	11.5	5020.	5652.	5100.	5742.	1220.	1373.
91	11.5	2280.	3335.	2430.	3554.	3120.	4564.
92	11.5	1150.	1530.	1300.	1730.	900.	1197.
93	11.8	1480.	1653.	4880.	5453.	4320.	4827.
94	11.4	3570.	5001.	2360.	3306.	2070.	2900.
95	6.9	32680.	43608.	2230.	2975.	5000.	6671.
96	11.2	1680.	1899.	1800.	2035.	4400.	4975.
97	11.1	2680.	3629.	2390.	3237.	2880.	3900.
98	7.1	1310.	1599.	2140.	2612.	1060.	1294.
99	11.4	2100.	2028.	1278.	1234.	2480.	2395.
100	9.8	7730.	9438.	4622.	5643.	4240.	5176.
101	6.9	520.	699.	712.	957.	440.	591.
102	11.1	1280.	1900.	1428.	2119.	4000.	5938.
103	6.6	11210.	13724.	14904.	18247.	5000.	6121.
104	7.7	3690.	3680.	3874.	3864.	5000.	4987.
105	9.6	5100.	6235.	17676.	21611.	5000.	6113.
106	7.8	2640.	3157.	2171.	2596.	3540.	4233.
107	11.4	920.	985.	2007.	2149.	2560.	2741.
108	7.0	5460.	5619.	5374.	5530.	9600.	9879.

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TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 lb	14 Ether Solubles ppm	15 lb	16 BOD ppm	17 lb
109	7.9	3920.	4799.	3775.	4621.	5000.	6121.
110	9.4	920.	1221.	1051.	1395.	1660.	2204.
111	6.8	3040.	2991.	3100.	3050.	6200.	6101.
112	11.2	9365.	6873.	13100.	9614.	10000.	7339.
113	12.0	1225.	1599.	1390.	1815.	2720.	3552.
114	9.3	17500.	17893.	14160.	14478.	5000.	5112.
115	8.5	7550.	6485.	6490.	5575.	4160.	3573.
116	11.6	2190.	2125.	3230.	3135.	1460.	1417.
117	11.9	7950.	7160.	7770.	6998.	5000.	4503.
118	11.2	2550.	1999.	3130.	2453.	4040.	3167.
119	11.4	930.	930.	1410.	1411.	2280.	2281.
120	7.7	8080.	7547.	8250.	7706.	5000.	4670.
121	8.9	1880.	1505.	1520.	1216.	3040.	2433.
122	10.9	1750.	1663.	2170.	2063.	4320.	4107.
123	10.9	1110.	936.	990.	835.	1980.	1671.
124	11.9	2075.	1401.	2410.	1628.	2340.	1580.
125	11.3	2100.	1856.	2260.	1997.	3680.	3253.
126	9.9	2100.	3422.	830.	1352.	1560.	2542.
127	8.6	5960.	9454.	3950.	6265.	5000.	7931.
128	10.8	4135.	5297.	2470.	3164.	4000.	5124.
129	10.8	1655.	1987.	1210.	1453.	1940.	2329.
130	10.7	2730.	3278.	920.	1104.	1450.	1741.
131	11.0	8460.	10865.	1660.	2132.	1760.	2260.
132	10.6	2495.	3337.	1840.	2461.	3920.	5243.
133	6.1	1750.	2052.	3460.	4057.	3040.	3564.
134	8.7	3975.	5536.	5160.	7186.	3600.	5014.
135	10.6	1470.	2363.	2400.	3859.	2880.	4630.

TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 lb	14 Ether Solubles ppm	15 lb	16 BOD ppm	17 lb
136	9.9	6422.	6491.	5700.	5761.	5000.	5054.
137	10.5	3750.	6192.	3800.	6275.	4320.	7133.
138	11.1	2840.	4263.	3190.	4788.	2340.	3512.
139	8.2	2650.	3465.	2440.	3190.	4080.	5335.
140	11.0	2295.	3066.	3160.	4221.	2420.	3233.
141	11.0	2275.	3661.	2710.	4362.	4720.	7597.
142	11.0	1635.	2290.	1800.	2522.	3600.	5044.
143	8.4	3120.	4303.	2130.	2938.	3120.	4303.
144	10.9	6080.	10435.	4450.	7637.	2100.	3604.
145	8.1	1420.	2510.	1270.	2245.	3780.	6687.
146	6.5	1020.	1752.	890.	1529.	2240.	3848.
147	0.0	0.	0.	0.	0.	0.	0.
148	0.0	0.	0.	0.	0.	0.	0.
149	6.8	1110.	1845.	2590.	4307.	2760.	4589.
150	10.3	900.	1745.	950.	1842.	1580.	3065.
151	8.0	1000.	1694.	950.	1609.	1610.	2728.
152	9.0	770.	1166.	480.	726.	700.	1060.
153	10.3	1100.	1974.	1200.	2153.	2060.	3697.
154	5.7	4500.	7430.	4880.	8058.	5000.	8256.
155	5.6	8460.	13165.	7830.	12185.	10000.	15562.
156	10.0	12170.	24927.	13520.	27693.	10000.	20483.
157	5.8	2630.	4342.	4380.	7232.	4800.	7926.
158	6.7	1710.	2723.	1480.	2357.	240.	382.
159	6.7	4350.	5173.	7450.	8860.	2580.	3068.
160	8.6	8630.	13732.	6860.	10916.	2580.	4105.
161	10.3	3310.	6492.	3550.	6963.	6240.	12240.
162	6.7	2650.	3182.	2090.	2510.	1460.	1753.

TABLE 24 (Continued)

RAW WASTE

1a Run No.	11 pH	12 Suspended Solids ppm	13 lb	14 Ether Solubles ppm	15 lb	16 BOD ppm	17 lb
163	10.9	2280.	2696.	2140.	2530.	10000.	11826.
164	11.2	1980.	2939.	2020.	2998.	3840.	5700.
165	7.2	2550.	2598.	2950.	3006.	3680.	3750.
166	8.8	2570.	3515.	1350.	1846.	1440.	1969.
167	11.4	2970.	3794.	3340.	4267.	7680.	9812.
168	10.5	8120.	8925.	10100.	11102.	10000.	10992.
169	11.1	4030.	3192.	3570.	2828.	2640.	2091.
170	11.0	2630.	2882.	3440.	3769.	5000.	5479.
171	10.7	2245.	2752.	3480.	4266.	1440.	1765.
172	11.0	2259.	2223.	2963.	2915.	2220.	2184.
173	5.4	3196.	3555.	2792.	3106.	5000.	5562.
174	11.0	1771.	1671.	2647.	2499.	2740.	2586.
175	10.7	778.	1213.	809.	1261.	1480.	2308.
176	7.6	3154.	5345.	3036.	5145.	4440.	7524.
177	6.7	2903.	4498.	2815.	4362.	5000.	7747.
178	11.3	1750.	3018.	1443.	2488.	2910.	5018.
179	11.4	5763.	7690.	5693.	7596.	10000.	13343.
180	10.0	1352.	1407.	5351.	5569.	10000.	10408.
181	12.2	1044.	1072.	1647.	1692.	3520.	3616.
182	11.0	5400.	5503.	6550.	6675.	10000.	10191.
183	11.4	5283.	6423.	5862.	7128.	10000.	12159.
184	11.8	2236.	2536.	3097.	3512.	4400.	4990.

TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
1	2.6	830.	905.	44.6	890.	970.	-20.2	2560.	2792.	-6.6
2	5.4	470.	579.	53.9	500.	616.	35.0	820.	1010.	18.8
3	2.5	1110.	1144.	41.8	1120.	1154.	55.9	1640.	1690.	-26.1
4	3.1	500.	580.	10.7	520.	603.	1.8	880.	1021.	20.7
5	3.9	900.	710.	75.8	910.	717.	71.6	900.	710.	83.9
6	5.3	460.	455.	89.8	897.	888.	87.3	1000.	990.	47.3
7	6.3	1950.	2003.	9.3	1640.	1685.	39.7	3760.	3863.	-51.6
8	4.6	60.	56.	90.7	110.	102.	89.1	300.	280.	72.4
9	3.8	240.	234.	79.6	190.	185.	80.2	380.	370.	82.8
10	4.5	380.	307.	29.6	250.	202.	34.2	580.	469.	-3.5
11	4.5	10.	5.	97.3	50.	25.	85.7	60.	31.	89.6
12	3.5	460.	441.	63.4	270.	259.	62.5	200.	192.	64.2
13	4.3	1820.	1590.	-35.8	1500.	1311.	-16.2	3700.	3233.	-277.5
14	4.3	59.	48.	54.6	60.	49.	50.0	60.	49.	80.0
15	6.1	17930.	16987.	-3.4	73240.	69389.	-36520.0	5000.	4737.	0.0
16	5.8	3040.	3458.	83.9	15180.	17268.	83.9	5000.	5687.	0.0
17	7.1	9058.	8158.	38.0	40290.	36290.	-90.6	5000.	4503.	0.0
18	6.2	44734.	52529.	-52.2	53360.	62659.	-62.4	5000.	5871.	0.0
19	5.7	3172.	3513.	71.1	7990.	8849.	33.5	2400.	2658.	52.3
20	7.6	2933.	4138.	-5.2	4110.	5799.	0.0	4080.	5757.	13.5
21	10.2	1862.	3161.	-40.6	1660.	2818.	10.2	2540.	4312.	-35.1
22	8.8	1920.	3109.	51.0	3030.	4907.	37.7	3280.	5312.	21.1
23	6.7	323.	462.	84.0	330.	472.	88.8	520.	745.	82.4
24	6.7	855.	1438.	71.0	820.	1380.	81.8	940.	1582.	72.6
25	5.6	1670.	1506.	45.8	2010.	1813.	38.1	2740.	2472.	49.6
26	6.5	10925.	13065.	-4.1	14910.	17831.	22.3	5360.	6410.	-7.2
27	6.0	6355.	6317.	8.2	5910.	5875.	26.9	5680.	5646.	-13.6

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TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
28	8.8	1300.	1489.	0.0	1315.	1506.	65.4	2220.	2543.	5.9
29	5.9	1690.	2043.	-56.4	2024.	2447.	2.0	4320.	5224.	-111.7
30	6.8	160.	167.	-33.3	192.	201.	82.9	440.	460.	85.3
31	6.8	2090.	2586.	18.9	2032.	2514.	34.5	4800.	5940.	3.9
32	6.7	480.	547.	-4.3	490.	559.	22.8	780.	889.	53.2
33	7.3	3330.	3632.	-3.4	4602.	5020.	-42.7	4560.	4974.	8.7
34	5.7	1200.	1443.	54.7	1192.	1433.	58.3	2020.	2429.	59.5
35	7.2	2495.	3254.	48.6	2555.	3332.	42.7	3120.	4069.	37.6
36	3.6	860.	1276.	27.1	710.	1054.	2.0	1050.	1558.	72.6
37	8.0	360.	561.	46.2	265.	413.	55.0	320.	499.	62.3
38	8.8	620.	872.	17.8	340.	478.	44.2	400.	563.	56.9
39	4.3	280.	425.	55.2	220.	334.	63.3	260.	395.	81.5
40	9.1	445.	597.	15.2	460.	617.	-1.0	1080.	1450.	35.7
41	7.6	530.	703.	75.5	605.	803.	67.8	1970.	2615.	-4.7
42	11.4	805.	938.	32.9	905.	1055.	39.6	1160.	1352.	-38.0
43	6.1	1450.	1630.	39.3	1250.	1405.	41.8	2960.	3327.	39.3
44	9.0	510.	381.	42.0	410.	306.	33.8	1530.	1143.	27.8
45	7.7	3290.	4840.	-22.7	3270.	4810.	1.2	4400.	6473.	9.8
46	12.0	8350.	7270.	-135.2	8650.	7531.	-137.6	4880.	4248.	-6.5
47	8.3	1670.	2033.	49.3	1550.	1887.	65.0	2160.	2630.	6.8
48	10.1	720.	773.	38.9	610.	655.	29.0	1370.	1471.	38.8
49	9.8	780.	908.	19.5	590.	686.	36.5	1110.	1292.	29.7
50	11.1	1220.	1135.	-50.6	1240.	1154.	32.2	1940.	1805.	49.4
51	8.0	1860.	2196.	15.8	1630.	1924.	16.4	2960.	3495.	-28.6
52	9.5	1810.	2391.	47.3	1150.	1519.	60.3	2400.	3170.	25.0
53	6.7	920.	1043.	35.6	820.	930.	46.7	1900.	2155.	31.1
54	6.1	300.	287.	18.9	360.	345.	7.6	520.	498.	29.7

TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
55	6.5	660.	736.	25.0	620.	691.	32.6	1860.	2075.	-14.8
56	5.1	640.	646.	59.7	440.	444.	22.8	1720.	1738.	27.7
57	6.0	2450.	2035.	55.8	2200.	1827.	61.0	5120.	4252.	52.5
58	2.6	730.	776.	21.5	860.	915.	30.6	870.	925.	54.2
59	4.1	4660.	4352.	35.9	570.	532.	87.8	2120.	1980.	67.4
60	8.8	1380.	1155.	73.4	1550.	1297.	69.9	2220.	1858.	78.3
61	8.8	1000.	1114.	78.6	1000.	1114.	77.9	2260.	2518.	72.8
62	5.7	970.	1016.	53.1	1280.	1340.	58.9	1840.	1927.	65.9
63	6.4	610.	584.	58.7	560.	536.	67.0	1010.	967.	54.0
64	7.6	1140.	1045.	31.3	1310.	1201.	0.7	1560.	1431.	35.5
65	6.8	660.	704.	25.8	500.	533.	66.2	1310.	1398.	29.5
66	6.5	360.	589.	66.0	280.	458.	84.6	560.	917.	70.2
67	6.3	190.	257.	72.0	120.	162.	68.4	620.	839.	-34.7
68	2.9	790.	1317.	-11.2	540.	900.	-58.8	1120.	1868.	24.8
69	6.0	2460.	3844.	85.0	4500.	7033.	61.3	3440.	5376.	31.2
70	3.6	790.	1565.	51.2	570.	1129.	-42.5	1170.	2318.	61.5
71	6.4	410.	649.	73.0	440.	697.	70.6	620.	982.	82.3
72	11.3	4300.	5522.	14.1	4540.	5830.	20.4	5000.	6421.	0.0
73	6.7	510.	592.	64.5	574.	666.	50.5	1320.	1532.	-26.9
74	4.2	740.	856.	89.4	604.	699.	91.1	800.	926.	73.6
75	6.3	985.	814.	55.8	679.	561.	72.3	1330.	1100.	63.0
76	6.4	2050.	2290.	63.5	1756.	1962.	67.2	3280.	3665.	31.6
77	6.8	2680.	3124.	64.3	2200.	2565.	67.5	3920.	4570.	9.2
78	8.1	8400.	9737.	-61.5	6015.	6972.	-28.4	4800.	5564.	9.0
79	6.3	2050.	2598.	32.0	1836.	2327.	39.6	2960.	3752.	27.4
80	6.1	825.	932.	68.5	794.	897.	67.1	1240.	1402.	42.8
81	6.3	3205.	3277.	-15.2	2961.	3027.	19.2	4320.	4417.	-68.7

TABLE 24 (Continued)

		SKIMMER UNIT EFFLUENT								
1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
82	6.5	737.	906.	-63.7	818.	1005.	36.1	1030.	1266.	52.3
83	3.7	725.	783.	65.4	723.	781.	73.8	1240.	1340.	74.1
84	4.1	1775.	1734.	79.3	1689.	1650.	82.9	2570.	2512.	73.2
85	4.4	950.	1178.	32.1	911.	1130.	27.6	1700.	2109.	26.7
86	4.2	230.	230.	84.6	150.	150.	87.6	260.	260.	82.4
87	6.2	2510.	2679.	33.0	2260.	2412.	44.6	2060.	2199.	53.1
88	8.9	8530.	10087.	0.6	9190.	10868.	-26.2	5280.	6244.	-4.7
89	6.1	890.	1128.	78.1	870.	1102.	80.7	1720.	2180.	67.4
90	3.8	620.	698.	87.6	750.	844.	85.2	880.	990.	27.8
91	8.8	1770.	2589.	22.3	1630.	2384.	32.9	2440.	3569.	21.7
92	6.4	920.	1224.	20.0	850.	1131.	34.6	1440.	1916.	-60.0
93	7.2	1750.	1955.	-18.2	2540.	2838.	47.9	2880.	3218.	33.3
94	6.8	4800.	6725.	-34.4	3910.	5478.	-65.6	5000.	7005.	-141.5
95	6.6	15330.	20456.	53.0	2860.	3816.	-28.2	5000.	6671.	0.0
96	6.4	910.	1029.	45.8	730.	825.	59.4	2140.	2420.	51.3
97	6.6	1250.	1693.	53.3	1120.	1516.	53.1	1680.	2275.	41.6
98	6.6	1180.	1440.	9.9	970.	1184.	54.6	1640.	2002.	-54.7
99	8.1	520.	502.	75.2	445.	429.	65.1	800.	772.	67.7
100	4.4	1720.	2100.	77.7	1457.	1778.	68.4	1540.	1880.	63.6
101	6.1	200.	268.	61.5	302.	406.	57.5	240.	322.	45.4
102	7.6	860.	1276.	32.8	2310.	3429.	-61.7	4960.	7363.	-23.9
103	5.9	3540.	4334.	68.4	3213.	3933.	78.4	5000.	6121.	0.0
104	6.7	1890.	1885.	48.7	1957.	1952.	49.4	5000.	4987.	0.0
105	8.4	3170.	3875.	37.8	2955.	3612.	83.2	5000.	6113.	0.0
106	6.4	2950.	3528.	-11.7	2563.	3065.	-18.0	5000.	5979.	-41.2
107	6.5	1060.	1135.	-15.2	1101.	1179.	45.1	2000.	2141.	21.8
108	5.7	2930.	3015.	46.3	3197.	3290.	40.5	5000.	5145.	47.9

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TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
109	4.4	110.	134.	97.1	345.	422.	90.8	730.	893.	85.4
110	6.9	1000.	1327.	-8.6	1027.	1363.	2.2	2020.	2682.	-21.6
111	5.5	850.	836.	72.0	1310.	1289.	57.7	780.	767.	87.4
112	6.1	19000.	13944.	-102.8	14620.	10729.	-11.6	5000.	3669.	50.0
113	6.9	1020.	1332.	16.7	1000.	1306.	28.0	1880.	2455.	30.8
114	6.3	5880.	6012.	66.4	4910.	5020.	65.3	5000.	5112.	0.0
115	6.9	23600.	20272.	-212.5	21360.	18348.	-229.1	5000.	4295.	-20.1
116	8.6	850.	825.	61.1	940.	912.	70.8	1360.	1320.	6.8
117	8.8	2760.	2485.	65.2	2310.	2080.	70.2	3600.	3242.	28.0
118	9.4	4550.	3567.	-78.4	4070.	3190.	-30.0	5000.	3919.	-23.7
119	9.9	850.	850.	8.6	930.	930.	34.0	1740.	1741.	23.6
120	6.7	1800.	1681.	77.7	1490.	1391.	81.9	4000.	3736.	20.0
121	6.0	850.	680.	54.7	710.	568.	53.2	1760.	1409.	42.1
122	8.9	1610.	1530.	8.0	2070.	1968.	4.6	4320.	4107.	0.0
123	7.8	260.	219.	76.5	230.	194.	76.7	620.	523.	68.6
124	8.6	2610.	1763.	-25.7	2850.	1925.	-18.2	1760.	1188.	24.7
125	6.4	2150.	1900.	-2.3	1140.	1007.	49.5	1920.	1697.	47.8
126	6.6	1070.	1743.	49.0	360.	586.	56.6	1700.	2770.	-8.9
127	5.9	1360.	2157.	77.1	650.	1031.	83.5	3440.	5456.	31.2
128	3.1	1005.	1287.	75.6	530.	678.	78.5	1370.	1755.	65.7
129	10.1	1260.	1513.	23.8	540.	648.	55.3	1960.	2353.	-1.0
130	10.3	1030.	1236.	62.2	580.	696.	36.9	1140.	1369.	21.3
131	10.4	2760.	3544.	67.3	1440.	1849.	13.2	1900.	2440.	-7.9
132	3.5	520.	695.	79.1	270.	361.	85.3	1220.	1632.	68.8
133	2.7	1570.	1840.	10.2	900.	1055.	73.9	3840.	4502.	-26.3
134	6.1	715.	995.	82.0	670.	933.	87.0	1600.	2228.	55.5
135	6.3	1375.	2210.	6.4	1190.	1913.	50.4	2380.	3826.	17.3

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TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
136	6.0	4800.	4851.	25.2	5010.	5064.	12.1	5000.	5054.	0.0
137	6.7	2280.	3765.	39.2	2430.	4012.	36.0	3500.	5779.	18.9
138	9.3	4450.	6680.	-56.6	4740.	7115.	-48.5	4960.	7445.	-111.9
139	6.8	4330.	5662.	-63.3	1530.	2000.	37.2	4310.	5636.	-5.6
140	5.7	125.	167.	94.5	200.	267.	93.6	2070.	2765.	14.4
141	7.3	4360.	7017.	-91.6	3750.	6036.	-38.3	5000.	8048.	-5.9
142	9.5	745.	1043.	54.4	730.	1022.	59.4	2070.	2900.	42.5
143	2.4	840.	1158.	73.0	830.	1144.	61.0	1000.	1379.	67.9
144	9.2	915.	1570.	84.9	1250.	2145.	71.9	1800.	3089.	14.2
145	5.9	350.	618.	75.3	230.	406.	81.8	580.	1025.	84.6
146	6.7	470.	807.	53.9	500.	859.	43.8	1400.	2405.	37.5
147	0.0	0.	0.	100.0	0.	0.	100.0	0.	0.	100.0
148	0.0	0.	0.	100.0	0.	0.	100.0	0.	0.	100.0
149	6.6	610.	1014.	45.0	880.	1463.	66.0	970.	1613.	64.8
150	7.6	550.	1066.	38.8	450.	872.	52.6	600.	1163.	62.0
151	5.9	1920.	3253.	-92.0	2030.	3440.	-113.6	4880.	8270.	-203.1
152	6.2	300.	454.	61.0	250.	378.	47.9	420.	636.	40.0
153	6.2	550.	987.	50.0	710.	1274.	40.8	1070.	1920.	48.0
154	5.8	3400.	5614.	24.4	3140.	5185.	35.6	5000.	8256.	0.0
155	7.7	4230.	6582.	50.0	4080.	6349.	47.8	7200.	11204.	27.9
156	6.5	2300.	4711.	81.1	2340.	4793.	82.6	5000.	10241.	50.0
157	6.0	800.	1321.	69.5	1700.	2807.	61.1	2100.	3467.	56.2
158	6.7	1000.	1592.	41.5	1290.	2054.	12.8	780.	1242.	-224.9
159	4.4	2490.	2961.	42.7	2190.	2604.	70.6	4480.	5327.	-73.6
160	6.8	6000.	9547.	30.4	5900.	9388.	13.9	820.	1304.	68.2
161	7.8	3660.	7179.	-10.5	3260.	6394.	8.1	6960.	13652.	-11.5
162	6.5	1110.	1333.	58.1	1160.	1393.	44.4	1730.	2077.	-18.4

TABLE 24 (Continued)

SKIMMER UNIT EFFLUENT

1a	21	22	23	24	25	26	27	28	29	30
		Suspended Solids			Ether Soluble			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
163	8.7	4580.	5416.	-100.8	4520.	5345.	-111.7	7040.	8325.	29.5
164	7.6	1720.	2553.	13.1	1700.	2523.	15.8	3360.	4987.	12.5
165	5.5	1790.	1824.	29.8	1330.	1355.	54.9	3200.	3261.	13.0
166	6.5	620.	848.	75.8	680.	930.	49.6	1330.	1819.	7.6
167	3.5	1260.	1609.	57.5	1260.	1609.	62.2	2420.	3092.	68.4
168	6.0	1930.	2121.	76.2	1440.	1582.	85.7	3200.	3517.	68.0
169	6.5	1170.	926.	70.9	1300.	1029.	63.5	1810.	1434.	31.4
170	10.4	3550.	3890.	-34.9	3700.	4054.	-7.5	5000.	5479.	0.0
171	5.6	1911.	2342.	14.8	1569.	1923.	54.9	2880.	3530.	-100.0
172	6.4	1703.	1675.	24.6	1473.	1449.	50.2	2640.	2598.	-18.9
173	4.0	4722.	5253.	-47.7	4426.	4924.	-58.5	5000.	5562.	0.0
174	4.5	1182.	1115.	33.2	1011.	954.	61.8	2140.	2020.	21.8
175	6.4	1752.	2732.	-125.1	1759.	2743.	-117.4	5000.	7797.	-237.8
176	5.9	1085.	1838.	65.5	972.	1647.	67.9	1900.	3219.	57.2
177	5.9	2179.	3376.	24.9	2156.	3340.	23.4	3840.	5950.	23.2
178	8.4	1226.	2114.	29.9	1158.	1997.	19.7	2130.	3673.	26.8
179	2.6	2070.	2762.	64.0	1897.	2531.	66.6	4240.	5657.	57.6
180	6.6	2275.	2367.	-68.2	1890.	1967.	64.6	4560.	4746.	54.4
181	11.5	804.	826.	22.9	650.	667.	60.5	1610.	1654.	54.2
182	6.2	3430.	3495.	36.4	3160.	3220.	51.7	7360.	7500.	26.4
183	6.5	4574.	5561.	13.4	3982.	4842.	32.0	2020.	2456.	79.8
184	6.1	890.	1009.	60.1	955.	1083.	69.1	1680.	1905.	61.8

TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
1	3.1	300.	327.	63.8	320.	349.	64.0	850.	927.	66.7
2	5.4	600.	739.	-27.6	590.	727.	-18.0	1360.	1676.	-65.8
3	5.2	310.	319.	72.0	290.	298.	74.1	700.	721.	57.3
4	3.0	210.	243.	58.0	210.	243.	59.6	520.	603.	40.9
5	4.3	400.	315.	55.5	400.	315.	56.0	790.	623.	12.2
6	3.2	20.	19.	95.6	90.	89.	89.9	200.	198.	80.0
7	7.0	220.	226.	88.7	210.	215.	87.1	520.	534.	86.1
8	4.6	100.	93.	-66.6	90.	84.	18.1	180.	168.	40.0
9	4.2	30.	29.	87.5	40.	39.	78.9	120.	117.	68.4
10	4.3	90.	72.	76.3	40.	32.	84.0	140.	113.	75.8
11	4.8	180.	93.	-1699.9	120.	62.	-140.0	200.	103.	-233.3
12	3.3	50.	48.	89.1	50.	48.	91.4	80.	76.	59.9
13	4.4	2230.	1949.	-22.5	2320.	2027.	-54.6	3600.	3146.	2.7
14	4.8	90.	73.	-52.5	60.	49.	0.0	180.	147.	-200.0
15	5.5	1380.	1307.	92.3	990.	937.	98.6	5000.	4737.	0.0
16	5.3	500.	568.	83.5	300.	341.	98.0	5040.	5733.	-0.8
17	6.7	872.	785.	90.3	670.	603.	98.3	1000.	900.	80.0
18	4.5	1284.	1507.	97.1	460.	540.	99.1	2380.	2794.	52.4
19	5.3	387.	428.	87.7	380.	420.	95.2	1330.	1473.	44.5
20	4.8	486.	685.	83.4	390.	550.	90.5	1230.	1735.	69.8
21	8.3	870.	1477.	53.2	790.	1341.	52.4	1150.	1952.	54.7
22	8.1	2720.	4405.	-41.6	2650.	4292.	12.5	3760.	6089.	-14.6
23	6.3	473.	677.	-46.4	660.	945.	-100.0	1030.	1475.	-98.0
24	4.3	180.	302.	78.9	130.	218.	84.1	280.	471.	70.2
25	4.0	200.	180.	88.0	160.	144.	92.0	280.	252.	89.7
26	4.1	850.	1016.	92.2	1680.	2009.	88.7	1170.	1399.	78.1
27	5.7	900.	894.	85.8	770.	765.	86.9	1360.	1352.	76.0

TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
28	5.3	600.	687.	53.8	363.	415.	72.3	660.	756.	70.2
29	3.8	410.	495.	75.7	232.	280.	88.5	630.	761.	85.4
30	4.6	180.	188.	-12.4	83.	86.	56.7	230.	240.	47.7
31	4.5	1510.	1868.	27.7	1856.	2297.	8.6	3120.	3861.	35.0
32	5.3	260.	296.	45.8	143.	163.	70.8	320.	365.	58.9
33	6.3	620.	676.	81.3	432.	471.	90.6	1130.	1232.	75.2
34	3.7	150.	180.	87.5	124.	149.	89.5	720.	865.	64.3
35	4.5	590.	769.	76.3	470.	613.	81.6	1020.	1330.	67.3
36	2.6	855.	1269.	0.5	735.	1091.	-3.5	1670.	2479.	-59.0
37	6.7	380.	592.	-5.5	255.	397.	3.7	580.	904.	-81.2
38	6.8	110.	154.	82.2	50.	70.	85.2	140.	197.	65.0
39	3.6	190.	288.	32.1	170.	258.	22.7	320.	486.	-23.0
40	7.9	195.	261.	56.1	245.	328.	46.7	460.	617.	57.4
41	4.7	40.	53.	92.4	30.	39.	95.0	140.	185.	92.8
42	3.7	105.	122.	86.9	195.	227.	78.4	220.	256.	81.0
43	4.8	400.	449.	72.4	220.	247.	82.4	1170.	1315.	60.4
44	6.4	130.	97.	74.5	170.	127.	58.5	1430.	1068.	6.5
45	6.5	1280.	1883.	61.0	970.	1427.	70.3	2800.	4119.	36.3
46	11.3	1070.	931.	87.1	2320.	2020.	73.1	4880.	4248.	0.0
47	6.3	300.	365.	82.0	130.	158.	91.6	500.	608.	76.8
48	7.4	380.	408.	47.2	140.	150.	77.0	420.	451.	69.3
49	4.3	130.	151.	83.3	70.	81.	88.1	100.	116.	90.9
50	4.4	250.	232.	79.5	140.	130.	88.7	400.	372.	79.3
51	6.3	770.	909.	58.6	370.	436.	77.3	1840.	2172.	37.8
52	5.6	300.	396.	83.4	120.	158.	89.5	340.	449.	85.8
53	5.1	140.	158.	84.7	40.	45.	95.1	220.	249.	88.4
54	5.2	210.	201.	30.0	140.	134.	61.1	280.	268.	46.1

TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
55	5.5	360.	401.	45.4	230.	256.	62.9	730.	814.	60.7
56	3.3	110.	111.	82.8	80.	80.	81.8	380.	384.	77.9
57	2.5	1470.	1221.	40.0	1820.	1511.	17.2	4000.	3322.	21.8
58	2.6	420.	446.	42.4	510.	542.	40.6	960.	1021.	-10.3
59	2.6	200.	186.	95.7	250.	233.	56.1	520.	485.	75.4
60	5.0	350.	293.	74.6	610.	510.	60.6	340.	284.	84.6
61	7.1	620.	690.	38.0	450.	501.	55.0	900.	1002.	60.1
62	3.7	110.	115.	88.6	150.	157.	88.2	160.	167.	91.3
63	4.5	50.	47.	91.8	80.	76.	85.7	140.	134.	86.1
64	2.8	250.	229.	78.0	280.	256.	78.6	620.	568.	60.2
65	4.8	550.	587.	16.6	330.	352.	34.0	860.	918.	34.3
66	4.4	270.	442.	25.0	10.	16.	96.4	60.	98.	89.2
67	5.4	40.	54.	78.9	20.	27.	93.3	300.	406.	51.6
68	2.7	140.	233.	82.2	110.	183.	79.6	300.	500.	73.2
69	4.1	250.	390.	89.8	310.	484.	93.1	490.	765.	85.7
70	3.6	310.	614.	60.7	200.	396.	64.9	420.	832.	64.1
71	5.8	350.	554.	14.6	240.	380.	45.4	340.	538.	45.1
72	7.1	1270.	1631.	70.4	1200.	1541.	73.5	3280.	4212.	34.3
73	6.1	245.	284.	51.9	165.	191.	71.2	440.	510.	66.6
74	3.4	320.	370.	56.7	260.	300.	56.9	430.	497.	46.2
75	6.1	1230.	1017.	-24.8	1317.	1089.	-93.9	3040.	2515.	-128.5
76	5.9	1380.	1542.	32.6	1252.	1399.	28.7	2880.	3218.	12.1
77	6.6	770.	897.	71.2	581.	677.	73.5	1200.	1399.	69.3
78	6.0	350.	405.	95.8	204.	236.	96.6	670.	776.	86.0
79	6.6	1000.	1267.	51.2	681.	863.	62.9	1400.	1774.	52.7
80	6.6	1560.	1764.	-89.0	1287.	1455.	-62.0	2380.	2691.	-91.9
81	5.7	225.	230.	92.9	12.	12.	99.5	200.	204.	95.3

TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
82	6.8	440.	540.	40.2	501.	615.	38.7	850.	1044.	17.4
83	3.8	360.	389.	50.3	301.	325.	58.3	1120.	1210.	9.6
84	3.3	560.	547.	68.4	440.	430.	73.9	1280.	1251.	50.1
85	4.1	400.	496.	57.8	323.	400.	64.5	920.	1141.	45.8
86	3.9	210.	210.	8.6	90.	90.	40.0	140.	140.	46.1
87	4.3	190.	202.	92.4	120.	128.	94.6	320.	341.	84.4
88	6.9	1130.	1336.	86.7	1880.	2223.	79.5	1220.	1442.	76.8
89	5.4	580.	735.	34.8	470.	595.	45.9	810.	1026.	52.9
90	3.4	320.	360.	48.3	370.	416.	50.6	520.	585.	40.9
91	5.0	390.	570.	77.9	260.	380.	84.0	400.	585.	83.6
92	3.4	400.	532.	56.5	350.	465.	58.8	770.	1024.	46.5
93	3.6	550.	614.	68.5	440.	491.	82.6	900.	1005.	68.7
94	6.1	230.	322.	95.2	240.	336.	93.8	400.	560.	92.0
95	5.8	680.	907.	95.5	700.	934.	75.5	1840.	2455.	63.2
96	5.1	250.	282.	72.5	80.	90.	89.0	180.	203.	91.5
97	5.8	400.	541.	68.0	350.	474.	68.7	540.	731.	67.8
98	5.9	180.	219.	84.7	230.	280.	76.2	380.	463.	76.8
99	8.6	1100.	1062.	-111.5	1042.	1006.	-134.1	2100.	2028.	-162.4
100	2.9	450.	549.	73.8	346.	422.	76.2	580.	708.	62.3
101	6.3	180.	241.	10.0	229.	307.	24.1	380.	510.	-58.3
102	4.9	370.	549.	56.9	202.	299.	91.2	730.	1083.	85.2
103	3.8	150.	183.	95.7	92.	112.	97.1	240.	293.	95.2
104	5.9	860.	857.	54.4	888.	885.	54.6	1320.	1316.	73.6
105	6.1	1650.	2017.	47.9	1209.	1478.	59.0	2800.	3423.	44.0
106	3.5	6368.	7615.	-115.8	463.	553.	81.9	480.	574.	90.4
107	4.8	500.	535.	52.8	323.	345.	70.6	730.	781.	63.5
108	5.8	450.	463.	84.6	452.	465.	85.8	1080.	1111.	78.4

TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
109	5.8	260.	318.	-136.3	59.	72.	82.8	180.	220.	75.3
110	4.1	150.	199.	85.0	161.	213.	84.3	340.	451.	83.1
111	3.7	570.	560.	32.9	610.	600.	53.4	400.	393.	48.7
112	4.4	210.	154.	98.8	200.	146.	98.6	360.	264.	92.8
113	5.7	316.	412.	69.0	220.	287.	78.0	300.	391.	84.0
114	9.9	425.	434.	92.7	250.	255.	94.9	1020.	1042.	79.6
115	6.8	265.	227.	98.8	300.	257.	98.5	520.	446.	89.6
116	7.3	550.	533.	35.2	410.	398.	56.3	1000.	970.	26.4
117	6.7	405.	364.	85.3	280.	252.	87.8	520.	468.	85.5
118	3.3	165.	129.	96.3	240.	188.	94.1	440.	344.	91.2
119	7.6	210.	210.	75.2	200.	200.	78.4	500.	500.	71.2
120	6.7	870.	812.	51.6	540.	504.	63.7	2000.	1868.	50.0
121	6.1	405.	324.	52.3	310.	248.	56.3	420.	336.	76.1
122	6.6	360.	342.	77.6	350.	332.	83.0	420.	399.	90.2
123	7.3	200.	168.	23.0	200.	168.	13.0	440.	371.	29.0
124	7.7	200.	135.	92.3	140.	94.	95.0	300.	202.	82.9
125	5.8	640.	565.	70.2	690.	609.	39.4	760.	671.	60.4
126	6.2	740.	1205.	30.8	210.	342.	41.6	930.	1352.	51.1
127	5.7	1350.	2141.	0.7	1330.	2109.	-104.6	1760.	2791.	48.8
128	3.4	600.	768.	40.2	530.	678.	0.0	950.	1216.	30.6
129	5.7	490.	588.	61.1	230.	276.	57.4	460.	552.	76.5
130	7.8	680.	816.	33.0	290.	348.	50.0	1010.	1212.	11.4
131	4.8	700.	899.	74.6	590.	757.	59.0	1940.	2491.	-2.1
132	4.2	340.	454.	34.6	200.	267.	25.9	400.	535.	67.2
133	2.8	885.	1037.	43.6	550.	644.	38.8	3060.	3588.	20.3
134	5.4	250.	348.	65.0	210.	292.	68.6	280.	389.	82.5
135	6.3	140.	225.	89.8	100.	160.	91.5	280.	450.	88.2

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AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles				BOD	
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
136	5.5	550.	555.	88.5	450.	454.	91.0	400.	404.	92.0
137	4.3	125.	206.	94.5	130.	214.	94.6	200.	330.	94.2
138	6.6	190.	285.	95.7	160.	240.	96.6	240.	360.	95.1
139	6.3	160.	200.	96.3	220.	287.	85.6	540.	706.	97.4
140	3.8	140.	187.	-12.0	360.	480.	-79.9	440.	587.	78.7
141	6.7	110.	177.	97.4	1080.	1738.	71.2	380.	611.	92.4
142	5.8	105.	147.	85.9	80.	112.	89.0	220.	308.	99.3
143	2.7	165.	227.	80.3	200.	275.	75.9	200.	275.	90.0
144	5.3	275.	472.	69.9	190.	326.	84.8	800.	1373.	55.5
145	5.5	380.	671.	-8.5	110.	194.	52.1	220.	388.	62.0
146	3.9	130.	223.	72.3	90.	154.	82.0	180.	309.	87.1
147	0.0	0.	0.	100.0	0.	0.	100.0	0.	0.	100.0
148	0.0	0.	0.	100.0	0.	0.	100.0	0.	0.	100.0
149	5.9	420.	698.	31.1	360.	598.	59.0	870.	1446.	10.3
150	6.3	140.	271.	74.5	110.	213.	75.5	120.	232.	20.0
151	4.5	390.	660.	79.6	290.	491.	85.7	360.	610.	92.6
152	4.6	160.	242.	46.6	50.	75.	80.0	120.	181.	71.4
153	4.6	310.	556.	43.6	130.	233.	81.6	280.	502.	73.8
154	5.5	90.	148.	97.3	20.	33.	99.3	120.	198.	97.6
155	6.4	360.	560.	91.4	360.	560.	91.1	850.	1322.	88.1
156	5.9	1080.	2212.	53.0	440.	901.	81.1	1050.	2150.	79.0
157	5.4	120.	198.	85.0	150.	247.	91.1	180.	297.	91.4
158	4.7	200.	318.	80.0	210.	334.	83.7	520.	828.	33.3
159	4.5	70.	83.	97.1	30.	35.	98.6	300.	356.	93.3
160	4.9	890.	1416.	85.1	180.	286.	96.9	140.	222.	82.9
161	6.8	290.	568.	92.0	240.	470.	92.6	420.	823.	93.9
162	4.6	50.	60.	95.4	90.	108.	92.2	140.	168.	91.9

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TABLE 24 (Continued)

AIR FLOTATION UNIT

1a	31	32	33	34	35	36	37	38	39	40
		Suspended Solids			Ether Solubles			BOD		
Run No.	pH	ppm	lb	Percent removed	ppm	lb	Percent removed	ppm	lb	Percent removed
163	4.8	100.	118.	97.8	170.	201.	96.2	240.	283.	96.5
164	4.7	310.	460.	81.9	280.	415.	83.5	680.	1009.	79.7
165	3.9	110.	112.	93.8	140.	142.	89.4	560.	570.	82.5
166	4.9	40.	54.	93.5	30.	41.	95.5	100.	136.	92.4
167	3.8	250.	319.	80.1	370.	472.	70.6	540.	689.	77.6
168	4.5	1300.	1428.	32.6	210.	230.	85.4	520.	571.	83.7
169	4.2	660.	522.	43.5	500.	396.	61.5	1130.	895.	37.5
170	6.4	300.	328.	91.5	220.	241.	94.0	600.	657.	88.0
171	5.2	221.	270.	88.4	120.	147.	92.3	220.	269.	92.3
172	5.6	208.	204.	87.7	197.	193.	86.6	340.	334.	87.1
173	3.3	492.	547.	89.5	459.	510.	89.6	1300.	1446.	74.0
174	3.4	343.	323.	70.9	323.	304.	68.0	740.	698.	65.4
175	6.3	493.	768.	71.8	394.	614.	77.6	940.	1466.	81.2
176	4.7	378.	640.	65.1	422.	715.	56.5	670.	1135.	64.7
177	4.0	125.	193.	94.2	134.	207.	93.7	340.	526.	91.1
178	7.6	428.	738.	65.0	295.	508.	74.5	380.	655.	82.1
179	2.5	670.	894.	67.6	664.	886.	64.9	1120.	1494.	73.5
180	3.3	516.	537.	77.3	350.	364.	81.4	770.	801.	83.1
181	4.0	102.	104.	87.3	64.	65.	90.1	200.	205.	87.5
182	5.7	233.	237.	93.2	146.	148.	95.3	960.	978.	86.9
183	6.5	683.	830.	85.0	381.	463.	90.4	1600.	1945.	20.7
184	4.0	243.	275.	72.6	222.	251.	76.7	240.	272.	85.7

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TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT 1a Run No.	 41 Turbidity JTU	 42 Oxygen ppm	 43 Temp °F
1	270.	7	144
2	470.	9	106
3	190.	10	108
4	150.	8	111
5	290.	7	110
6	110.	7	111
7	220.	9	111
8	80.	9	108
9	60.	8	100
10	90.	10	102
11	100.	10	105
12	60.	10	107
13	100.	9	103
14	80.	6	97
15	700.	9	108
16	120.	9	110
17	560.	12	110
18	290.	10	112
19	200.	11	110
20	1300.	10	104
21	770.	10	100
22	1600.	10	110
23	850.	10	98
24	150.	10	100
25	120.	10	105
26	580.	11	120
27	540.	9	116

TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT 1a Run No.	 41 Turbidity JTU	 42 Oxygen ppm	 43 Temp °F
28	800.	7	115
29	250.	10	114
30	110.	11	111
31	820.	10	106
32	230.	10	106
33	830.	10	105
34	120.	9	101
35	650.	8	110
36	350.	11	102
37	800.	10	105
38	130.	9	101
39	180.	10	100
40	260.	9	103
41	50.	9	105
42	100.	9	102
43	750.	10	111
44	180.	3	103
45	1100.	2	115
46	1600.	1	114
47	280.	3	107
48	220.	10	105
49	90.	7	104
50	230.	11	102
51	1000.	10	107
52	300.	5	116
53	120.	5	107
54	160.	6	113

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TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT			
1a Run No.	41 Turbidity JTU	42 Oxygen ppm	43 Temp °F
55	260.	6	106
56	110.	5	100
57	670.	10	106
58	250.	10	108
59	120.	10	108
60	300.	10	110
61	450.	18	107
62	55.	10	109
63	65.	9	113
64	190.	10	111
65	350.	10	107
66	20.	10	109
67	20.	10	113
68	85.	10	105
69	130.	10	115
70	150.	10	108
71	230.	9	111
72	1700.	10	109
73	260.	10	107
74	130.	10	113
75	1230.	10	111
76	1900.	10	109
77	530.	10	110
78	170.	10	111
79	420.	10	110
80	1100.	10	109
81	90.	10	111

TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT			
1a Run No.	41 Turbidity JTU	42 Oxygen ppm	43 Temp °F
82	450.	10	110
83	210.	8	112
84	200.	7	115
85	170.	10	110
86	400.	10	111
87	240.	10	118
88	580.	10	102
89	430.	10	110
90	120.	10	112
91	310.	10	110
92	280.	10	109
93	350.	10	112
94	150.	10	110
95	180.	10	112
96	70.	10	114
97	320.	10	111
98	150.	6	118
99	290.	10	113
100	170.	9	113
101	160.	10	105
102	470.	10	106
103	110.	10	109
104	630.	10	122
105	440.	10	116
106	270.	10	118
107	420.	10	117
108	340.	10	112

TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT

1a Run No.	41 Turbidity JTU	42 Oxygen ppm	43 Temp °F
109	110.	10	111
110	180.	10	110
111	240.	10	117
112	120.	10	116
113	230.	10	113
114	250.	8	114
115	1000.	10	122
116	530.	3	118
117	200.	9	114
118	2300.	10	121
119	290.	9	118
120	1000.	10	115
121	170.	10	127
122	1500.	10	121
123	290.	10	123
124	110.	10	122
125	530.	10	124
126	400.	10	114
127	530.	10	112
128	270.	9	110
129	490.	0	106
130	460.	8	115
131	590.	10	115
132	230.	10	106
133	630.	10	115
134	220.	5	107
135	130.	7	102

TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT

1a Run No.	41 Turbidity JTU	42 Oxygen ppm	43 Temp °F
136	420.	3	111
137	100.	5	113
138	180.	10	106
139	120.	4	99
140	210.	10	102
141	90.	10	105
142	75.	11	106
143	80.	10	107
144	160.	4	94
145	100.	5	97
146	80.	4	99
147	0.	0	0
148	0.	0	0
149	390.	0	110
150	90.	0	100
151	150.	0	107
152	85.	0	102
153	100.	0	101
154	45.	0	106
155	350.	0	112
156	500.	0	114
157	110.	0	109
158	280.	0	106
159	65.	0	113
160	55.	0	113
161	210.	0	106
162	45.	0	108

TABLE 24 (Continued)

AIR FLOTATION UNIT EFFLUENT			
1a Run No.	41 Turbidity JTU	42 Oxygen ppm	43 Temp °F
163	80.	0	118
164	20.	0	114
165	100.	0	116
166	80.	0	114
167	150.	0	118
168	150.	0	121
169	320.	0	127
170	180.	0	123
171	200.	0	117
172	270.	0	117
173	190.	0	113
174	220.	0	118
175	450.	0	105
176	460.	0	99
177	140.	0	100
178	420.	0	103
179	340.	0	106
180	230.	0	117
181	70.	0	112
182	200.	0	113
183	620.	0	114
184	180.	0	115

APPENDIX D

OIL RECOVERY SYSTEM DATA

TABLE 25

OIL RECOVERY SYSTEM OPERATING DATA

Run No.	Date Skims Collected	Polymer Used	Date Cent. Run
1	6/10	400.00	6/12
2	6/11	400.00	6/17
3	6/15	400.00	6/18
4	6/21	400.00	6/24
5	6/21	400.00	6/24
6	6/24	400.25	6/25
7	6/25	250.00	6/29
8	6/29	250.00	7/10
10	7/3	20.00	8/3
11	8/4	670.00	8/5
12	8/5	670.00	8/6
13	8/6	670.00	8/7
14	8/10	250.00	8/11
15	8/11	250.40	8/12
16	8/12	400.00	8/13
17	8/17	400.00	8/18
18	8/20	20.00	8/21
19	8/21	20.00	8/24
20	8/24	400.00	8/25
21	8/25	400.00	8/26
22	9/3	670.00	9/4
23	9/4	670.00	9/8
24	9/10	670.00	9/11
25	9/11	670.00	9/14
26	9/15	20.00	9/16
27	9/18	20.00	9/21
28	9/21	250.00	9/22
29	9/22	250.00	9/23
30	9/23	250.00	9/24
31	9/24	250.00	9/25
32	9/28	400.00	9/29
33	9/29	400.00	9/30
34	10/1	400.00	10/2

TABLE 25 (Continued)

DELAVAL MACHINE DATA

Run No.	Ring Dam No.	Operating Water		On Feed Cycle sec.
		psi	°F	
1	119	20	135	60
2	116	20	148	90
3	116	20	162	90
4	116	20	155	90
5	116	20	167	90
6	116	20	155	60
7	116	20	157	90
8	116	20	160	90
10	116	20	155	50
11	116	22	150	60
12	116	22	150	45
13	116	22	150	45
14	116	22	152	45
15	116	22	155	45
16	116	22	152	45
17	116	22	149	45
18	116	22	150	45
19	116	22	152	45
20	116	22	150	45
21	116	22	150	45
22	116	22	148	45
23	114	26	150	45
24	114	27	150	45
25	114	27	150	45
26	114	27	150	45
27	114	27	148	45
28	114	27	147	45
29	114	26	146	45
30	114	26	156	45
31	114	26	140	45
32	114	26	140	45
33	114	26	140	45
34	114	26	150	45

TABLE 25 (Continued)

	SKIMMINGS TREATMENT			FEED TO CYCLONE OR DELAVAL			
Run No.	Skimmings gal.	50% NaOH lb	66°Be H_2SO_4 lb	Pres. psi	Temp °F	lb/ cycle	lb/ min
1	2644	241	237	34	170	170.00	136.00
2	4553	285	434	36	170	206.00	117.71
3	5777	351	290	37	188	206.75	118.14
4	5973	373	395	37	180	211.50	120.85
5	0	0	0	34	174	234.20	133.82
6	4700	0	0	40	180	152.30	121.84
7	6022	439	500	0	180	203.70	116.40
8	4700	570	605	35	180	204.00	116.57
10	0	0	0	0	180	0.00	0.00
11	4700	636	842	25	184	152.50	122.00
12	3231	285	526	38	180	114.50	114.50
13	5679	483	526	38	180	122.80	122.80
14	4700	439	842	38	180	113.50	113.50
15	2840	373	290	38	182	115.50	115.50
16	6316	0	0	38	182	117.00	117.00
17	4798	0	605	38	182	115.00	115.00
18	5679	527	474	38	182	118.00	118.00
19	5337	636	500	38	180	118.50	118.50
20	5679	549	342	38	164	105.50	105.50
21	5679	724	395	0	160	94.00	94.00
22	5288	724	869	39	165	106.50	106.50
23	0	0	0	38	150	0.00	0.00
24	5288	724	790	38	179	122.00	122.00
25	0	0	0	38	178	120.00	120.00
26	0	0	0	40	182	114.00	114.00
27	0	0	0	38	182	111.00	111.00
28	0	0	0	40	160	111.50	111.50
29	0	0	0	40	164	108.00	108.00
30	0	0	0	38	166	112.50	112.50
31	0	0	0	40	166	114.00	114.00
32	0	0	0	0	0	0.00	0.00
33	0	0	0	40	155	116.00	116.00
34	0	0	0	40	170	114.50	114.50

TABLE 25 (Continued)

		OIL PHASE				WATER PHASE	
				Back Pressure			
Run No.	Temp °F	lb/ cycle	lb/ cycle	Air psi	Water psi	lb/ cycle	lb/ cycle
1	0	37.50	30.00	0	0	90.00	72.00
2	162	43.50	24.85	10	15	112.90	64.51
3	188	61.50	35.14	14	14	98.00	56.00
4	162	63.00	36.00	16	15	100.00	57.14
5	162	74.50	42.57	16	15	108.20	61.82
6	167	13.50	10.80	16	15	80.80	71.83
7	165	40.00	22.85	10	0	110.20	62.97
8	0	29.00	16.57	10	25	122.50	70.00
10	0	40.00	36.92	15	20	0.00	0.00
11	0	43.50	34.80	0	0	73.50	58.80
12	0	39.00	39.00	10	25	49.00	49.00
13	0	25.00	25.00	10	25	65.30	65.29
14	0	37.00	37.00	10	25	45.00	45.00
15	0	33.00	33.00	10	25	52.50	52.50
16	0	35.00	35.00	10	25	54.00	54.00
17	0	33.00	33.00	10	25	52.00	52.00
18	0	35.00	35.00	10	25	49.00	49.00
19	0	46.50	46.50	10	25	42.00	42.00
20	0	25.00	25.00	10	25	52.50	52.50
21	0	25.00	25.00	10	25	39.00	39.00
22	0	20.00	20.00	10	25	53.00	53.00
23	0	0.00	0.00	10	25	0.00	0.00
24	0	35.00	35.00	10	25	45.00	45.00
25	0	36.00	36.00	10	25	44.00	44.00
26	0	29.00	29.00	10	25	42.00	42.00
27	0	36.00	36.00	10	25	32.00	32.00
28	0	38.00	38.00	10	25	32.50	32.50
29	0	28.00	28.00	10	28	34.00	34.00
30	0	22.00	22.00	10	28	51.50	51.50
31	0	30.00	30.00	10	28	46.00	46.00
32	0	0.00	0.00	0	0	0.00	0.00
33	0	24.00	24.00	10	28	52.00	52.00
34	0	17.00	17.00	10	30	57.50	57.50

TABLE 25 (Continued)

	CYCLONE	SLUDGE	DELAVAL	SLUDGE	TOTAL	SLUDGE
Run No.	lb/ cycle	lb/ min	lb/ cycle	lb/ min	lb/ cycle	lb/ min
1	17.00	13.60	25.50	20.40	42.50	34.00
2	24.50	14.00	25.50	14.57	50.00	28.57
3	26.25	15.00	21.00	12.00	47.25	27.00
4	25.00	14.28	23.50	13.42	48.50	27.71
5	28.00	16.00	23.50	13.42	51.50	29.42
6	18.50	14.80	30.50	24.40	49.00	39.20
7	30.00	17.14	23.50	13.42	53.50	30.57
8	29.00	16.57	23.50	13.42	52.50	30.00
10	15.00	13.84	0.00	0.00	0.00	0.00
11	19.50	15.60	16.00	12.80	35.50	28.40
12	0.00	0.00	0.00	0.00	26.50	26.50
13	15.00	15.00	17.50	17.50	32.50	32.50
14	15.00	15.00	16.50	16.50	31.50	31.50
15	15.50	15.50	14.50	14.50	30.00	30.00
16	14.00	14.00	14.00	14.00	28.00	28.00
17	14.00	14.00	16.00	16.00	30.00	30.00
18	15.50	15.50	18.50	18.50	34.00	34.00
19	15.00	15.00	15.00	15.00	30.00	30.00
20	15.00	15.00	13.00	13.00	28.00	28.00
21	15.00	15.00	15.00	15.00	30.00	30.00
22	15.50	15.50	18.00	18.00	33.50	33.50
23	0.00	0.00	0.00	0.00	0.00	0.00
24	15.00	15.00	27.00	27.00	42.00	42.00
25	15.50	15.50	24.50	24.50	40.00	40.00
26	15.00	15.00	28.00	28.00	43.00	43.00
27	15.50	15.50	27.50	27.50	43.00	43.00
28	14.00	14.00	27.00	27.00	41.00	41.00
29	17.50	17.50	28.50	28.50	46.00	46.00
30	15.00	15.00	24.00	24.00	39.00	39.00
31	15.00	15.00	23.00	23.00	38.00	38.00
32	Not used.		0.00	0.00	0.00	0.00
33	15.00	15.00	25.00	25.00	40.00	40.00
34	15.00	15.00	25.00	25.00	40.00	40.00

TABLE 26

OIL RECOVERY SYSTEM SAMPLE ANALYSES

FEED

Run No.	Moist. %	Ether Sol %	Ether a) Insol %	Ash %	pH
1	73.53*	21.49*	4.97*	2.43*	3.5
2	75.55*	22.51*	3.89*	1.91*	1.1*
3	49.00	5.27	45.73	1.30	2.3
4	62.10	30.60	7.20	2.50	2.0
5	62.10	30.60	7.20	2.50	2.0
6	85.10	11.40	3.50	1.90	3.4
7	86.10	13.30	0.60	2.20	5.1
8	79.70	14.70	5.60	2.10	2.6
10	53.50	35.20	11.30	4.50	2.6
11	61.00	34.90	4.10	4.00	2.4
12	60.10	40.40	-0.50	2.80	3.5
13	70.80	25.50	3.70	2.50	3.3
14	62.20	35.80	2.00	2.90	2.1
15	59.90	30.20	8.90	2.20	2.9
16	63.70	32.30	4.00	2.80	2.4
17	46.80	37.00	16.20	3.20	3.3
18	74.90	20.10	5.00	3.00	3.3
19	66.40	28.20	5.40	3.10	2.0
20	68.10	26.50	5.40	3.10	3.3
21	71.20	23.10	5.70	3.10	2.9
22	76.20	18.80	5.00	2.00	3.0
23	73.70	17.70	8.60	2.30	3.2
24				2.20	2.8
25	54.90	35.60	9.50	2.30	2.9
26	66.50	28.30	5.20	2.90	3.4
27	60.40	36.20	3.40	1.40	2.4
28	60.40	36.80	2.80	0.90	2.2
29	60.00	35.30	4.70	1.80	1.7
30	74.98*	20.76*	4.25*	1.52*	2.1
31	62.80	33.20	4.00	1.40	2.0
32	66.00	30.20	3.80	1.50	2.1
33	74.80	21.80	3.40	0.40	3.2
34	82.00	15.50	2.50	1.00	3.0

a) Calculated from: Ether Insol, % = 100 - (% Moist. + % Ether Sol)

* Calculated from material balance

TABLE 26 (Continued)

	OIL PHASE			WATER PHASE		
Run No.	Moist. %	Ether Sol %	Ether[a] Insol %	Ash %	Moist. %	Ether Sol %
1	8.80	84.70	6.50	0.60	92.30	3.70
2	1.00	86.09	12.91	0.10	97.30	0.56
3	0.20	92.41	7.39	0.10	97.60	0.80
4	1.20	98.60	0.16	0.10	93.70	0.56
5	2.50	97.20	0.27	0.20	93.10	0.90
6	0.80	99.10	0.09	0.80	96.30	1.80
7	7.10	90.90	2.00	4.50	95.60	2.90
8	2.20	93.80	4.00	0.30	95.30	1.00
10	1.80	97.80	0.44	0.25	95.20	0.51
11	0.57	99.40	0.01	0.02	96.60	0.55
12	0.87	98.60	0.57	0.18	98.00	1.00
13	0.79	99.20	0.06	0.15	97.20	0.47
14	1.00	98.70	0.30	0.11	91.40	0.11
15	0.83	98.10	1.07	0.13	95.20	0.15
16	0.92	97.50	1.58	0.08	93.90	0.47
17	0.79	98.30	0.91	0.21	92.20	0.39
18	0.45	98.50	1.10	0.13	96.30	0.20
19	34.30	62.30	3.40	1.50	92.60	0.03
20	0.83	97.60	1.60	0.15	95.80	0.24
21	0.80	96.50	2.70	0.49	91.10	4.10
22	0.54	99.40	0.06	0.20	93.10	0.71
23	2.70	98.20	-0.90	0.26	99.60	1.18
24	1.40	98.40	0.20	2.40	95.00	0.60
25	0.62	98.60	0.80	0.10	93.80	2.80
26	0.58	99.50	-0.08	0.16	92.40	3.10
27	0.59	99.10	0.31	0.10	47.20	18.30
28	1.40	98.40	0.20	0.10	92.60	1.30
29	0.59	98.80	0.61	0.10	93.10	1.10
30	0.52	99.00	0.48	0.10	93.90	1.10
31	0.39	99.90	0.71	0.10	94.70	0.60
32	0.42	99.00	0.58	5.30	99.10	0.30
33	0.72	98.60	0.68	0.10	95.40	0.40
34	0.33	99.10	0.57	0.20	95.80	1.20

a) Calculated from: Ether Insol, % = 100 - (% Moist. + % Ether Sol)

TABLE 26 (Continued)

	WATER PHASE			CYCLONE SLUDGE			
Run No.	Ether[a] Insol %	Ash %	pH	Moist. %	Ether Sol %	Ether[a] Insol %	Ash %
1	4.00	2.60	3.5	89.70	4.20	6.10	4.40
2	2.14	2.30	1.1	92.20	7.52	0.28	2.40
3	1.60	1.20	2.3	91.90	4.62	3.48	1.60
4	5.76	3.40	2.2	86.10	7.30	6.60	3.50
5	6.00	3.40	1.9	89.90	4.70	5.40	3.90
6	1.90	1.30	3.3	89.70	5.40	4.90	2.80
7	1.50	1.50	4.7	93.30	4.50	2.20	1.90
8	3.70	2.40	2.3	93.70	2.00	4.30	3.60
10	4.29	5.70	2.3	90.40	7.50	2.10	7.10
11	2.85	4.40	2.1	90.40	8.10	1.50	6.60
12	1.00	2.30	2.7	0.00	0.00	0.00	0.00
13	2.33	5.60	2.8	91.20	7.10	1.70	2.20
14	8.49	4.20	2.1	90.60	3.90	5.50	5.20
15	4.65	3.00	2.1	86.40	7.60	6.00	4.10
16	5.63	3.80	2.6	84.40	5.30	10.30	5.40
17	7.41	3.70	2.7	85.70	3.40	11.90	4.60
18	3.50	2.80	2.8	85.40	7.90	6.70	5.00
19	7.30	4.20	1.9	63.80	30.10	6.10	3.80
20	4.00	2.80	2.9	80.20	8.40	11.40	7.40
21	4.80	3.20	2.9	91.00	2.10	6.90	5.30
22	6.20	2.80	2.8	85.10	6.31	8.59	3.00
23	-0.78	1.60	3.2	93.90	2.42	3.68	2.30
24	4.40	3.00	2.7	92.50	1.70	5.80	3.80
25	3.40	1.80	2.9	91.20	3.90	4.90	4.00
26	4.50	2.90	3.0	86.20	7.20	6.60	4.10
27	34.50	1.40	2.4	59.80	39.00	1.20	1.70
28	6.10	0.90	2.1	93.40	3.90	2.70	1.70
29	5.80	2.90	1.8	65.90	28.10	6.00	1.90
30	5.00	1.70	2.1	88.10	6.10	5.80	3.10
31	4.70	2.00	1.9	88.20	6.00	5.80	2.20
32	0.60	2.30	2.1		Not used.		
33	4.20	1.50	2.1	89.20	5.10	5.70	2.10
34	3.00	1.30	2.6	93.10	3.70	3.20	1.60

a) Calculated from: Ether Insol, % = 100 - (% Moist. + Ether Sol)

TABLE 26 (Continued)

	DELAVAL SLUDGE				TOTAL SLUDGE			
Run No.	Moist. %	Ether Sol %	Ether[a)] Insol %	Ash %	Moist. %	Ether Sol %	Ether[a)] Insol %	Ash %
1	91.70*	2.86*	5.43*	3.23*	90.90	3.40	5.70	3.70
2	89.25*	25.32*	-0.26*	2.79*	90.70	16.60	0.00	2.60
3	87.30	10.44	2.26	3.80	90.74*	7.21*	2.94*	2.58*
4	89.50	3.00	7.50	3.70	87.71*	5.21*	7.03*	3.59*
5	88.60	3.60	7.80	3.60	89.31*	4.20*	6.49*	3.76*
6	82.61*	10.54*	6.84*	3.76*	85.29	8.60	6.11	3.40
7	96.30	1.70	2.00	1.60	94.57*	3.27*	2.11*	1.77*
8	93.30	0.10	6.60	2.70	93.49*	1.15*	5.23*	3.14*
10					0.00	0.00	0.00	0.00
11	91.73*	6.54*	1.72*	5.71*	91.00	7.40	1.60	6.20
12					91.40	8.30	0.30	4.80
13	96.58*	2.82*	0.58*	5.17*	94.10	4.80	1.10	3.80
14	85.44*	5.42*	9.12*	4.81*	87.90	4.70	7.40	5.00
15	86.40*	7.60*	6.00*	4.09*	86.40	7.60	6.00	4.10
16	86.40*	6.90*	6.70*	5.00*	85.40	6.10	8.50	5.20
17	81.95*	2.95*	14.22*	7.97*	83.70	3.16	13.14	6.40
18	76.57*	12.31*	11.11*	6.65*	80.60	10.30	9.10	5.90
19	85.80*	3.50*	10.70*	6.20*	74.80	16.80	8.40	5.00
20	70.50*	18.52*	10.96*	5.89*	75.70	13.10	11.20	6.70
21	81.00*	11.90*	7.10*	4.10*	86.00	7.00	7.00	4.70
22	85.28*	10.21*	4.49*	5.41*	85.20	8.41	6.55	4.30
23	0.00	0.00	0.00	0.00	87.80	2.27	9.93	1.90
24	93.74*	1.54*	4.71*	3.64*	93.30	1.60	5.10	3.70
25	95.44*	1.45*	3.10*	2.20*	93.80	2.40	3.80	2.90
26	95.87*	1.97*	2.14*	1.64*	92.50	3.80	3.70	2.50
27	92.32*	-7.90*	15.58*	3.26*	80.60	9.00	10.40	2.70
28	97.34*	-0.20*	2.85*	2.30*	96.00	1.20	2.80	2.10
29	87.04*	2.92*	10.03*	2.70*	79.00	12.50	8.50	2.40
30	94.43*	0.41*	5.15*	1.47*	92.00	2.60	5.40	2.10
31	88.36*	5.00*	6.62*	2.36*	88.30	5.40	6.30	2.30
32	92.50	1.70*	5.80*	2.90*	92.50	1.70	5.80	2.90
33	93.04*	2.38*	4.58*	1.78*	91.60	3.40	5.00	1.90
34	93.10*	2.58*	4.32*	1.92*	93.10	3.00	3.90	1.80

a) Calculated from: Ether Insol, % = 100 - (% Moist. + % Ether Sol)

* Calculated from material balance

TABLE 27

OIL AND ASH DISTRIBUTION TO DELAVAL AND CYCLONE STREAMS

	OIL DISTRIBUTION, FRACTION TO:			ASH DISTRIBUTION, FRACTION TO:			
Run No.	Oil	Total Sludge	Water	Oil	Total Sludge	Water	Cyclone Sludge
1	0.8694	0.0395	0.0911	0.0544	0.3806	0.5664	0.1810
2	0.8076	0.1789	0.0136	0.0110	0.3304	0.6599	0.1494
3	0.9314	0.0558	0.0128	0.0252	0.4996	0.4820	0.1721
4	0.9598	0.0390	0.0086	0.0119	0.3292	0.6430	0.1654
5	1.0104	0.0301	0.0135	0.0254	0.3307	0.6283	0.1865
6	0.7705	0.2427	0.0930	0.0373	0.5757	0.4034	0.1790
7	1.3420	0.0645	0.1179	0.4016	0.2113	0.3688	0.1271
8	0.9070	0.0201	0.0408	0.0203	0.3848	0.6862	0.2436
10							
11	0.8124	0.0493	0.0075	6.8872	0.3608	0.5301	0.2109
12	0.8312	0.0475	0.0105	0.0218	0.3967	0.3515	0.0000
13	0.7919	0.0498	0.0098	0.0122	0.4022	1.1911	0.1074
14	0.8987	0.0364	0.0012	0.0123	0.4785	0.5742	0.2369
15	0.9280	0.0653	0.0022	0.0168	0.4840	0.6198	0.2500
16	0.9029	0.0451	0.0067	0.0085	0.4444	0.6263	0.2307
17	0.7623	0.0222	0.0047	0.0188	0.5217	0.5228	0.1750
18	0.9056	0.0919	0.0025	0.0132	0.5862	0.4009	0.2264
19	0.8669	0.1508	0.0003	0.1898	0.4083	0.4801	0.1551
20	0.8727	0.1311	0.0045	0.0114	0.5736	0.4494	0.3393
21	1.1110	0.0967	0.0736	0.0420	0.4838	0.4282	0.2728
22	0.9929	0.1407	0.0187	0.0129	0.4664	0.4804	0.1505
23	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
24	0.9734	0.0189	0.0076	0.2250	0.4162	0.3616	0.1526
25	0.8308	0.0224	0.0288	0.0130	0.4202	0.2869	0.2246
26	0.8943	0.0506	0.0403	0.0140	0.3251	0.3684	0.1860
27	0.8878	0.0963	0.0820	0.0231	0.7471	0.2882	0.1605
28	0.9112	0.0110	0.0102	0.0378	0.8579	0.2914	0.2371
29	0.7256	0.5128	0.0098	0.0144	0.5679	0.5072	0.1710
30	0.9325	0.0434	0.0242	0.0128	0.4789	0.5118	0.2719
31	0.7918	0.0542	0.0072	0.0187	0.5476	0.5784	0.2007
32	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
33	0.9357	0.0537	0.0082	0.0517	1.6370	1.6810	0.6788
34	0.9492	0.0676	0.0388	0.0296	0.6288	0.6528	0.2096